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W. J. Brown

# CASSIER'S MAGAZINE.

VOL. VII. NOVEMBER, 1894. No. 37.

## JOHN ERICSSON, THE ENGINEER.

JULY 31, 1803—MARCH 8, 1889.

*By William Conant Church.*

It was the expressed wish of Captain Ericsson that his biography should be written by the author of this article, if at all, for he was singularly indifferent as to posthumous fame. In the twelve or fifteen thousand letters and manuscripts left by him, and transferred to the writer by his executors, is found abundant material for the Life of Ericsson, to be published during the present year. It is hoped that these articles will serve to make Ericsson known to the world as he was known to his friends—as one of the most generous-hearted and public-spirited of men, no less than one of the foremost of the world's great engineers.

AS the last hour of life was drawing to its close, John Ericsson called to his bedside his faithful friend and secretary, and, looking into his face with a smile, said: "Taylor, this rest is magnificent; more beautiful than words can tell."

For the first time in his wonderful career of threescore and ten years of active professional work, Ericsson seemed able to entertain the idea of rest without responsibility. "Providence," he once said, "has given me greater abilities for use, within certain limits, than to any other mortal, and I will be a faithful steward." This was no declaration of egotism, but the sober statement of a fact, in a letter to a relative who could understand the spirit in which the assertion was made.

How faithful Ericsson was in his stewardship the story of his life will tell. It seems impossible that any one man could have accomplished what he did, within the compass of a single lifetime; identifying himself in so many ways with those mechanical changes which separate the nineteenth century so widely from all that preceded it. In the year in which Ericsson was born, Robert Fulton launched his first steamboat upon the Seine, and the far-sighted Napoleon declared that its success would "change the face of the world." In the year that Ericsson reached his majority, the citizens of Louisville celebrated with public ceremonies the completion, in fifteen and a quarter days, of a steamboat voyage from New Orleans, which now occupies less than five days. Not a steamboat was then afloat upon the ocean, not a locomotive in motion upon the land, and land carriage, not having passed beyond the stage of traction by muscle-power, was practically where it had been from the beginning.

We all know the changes that have come since then; changes which make it possible for a London "bagman" to learn more of the great world, by actual contact, than was known even to Marco

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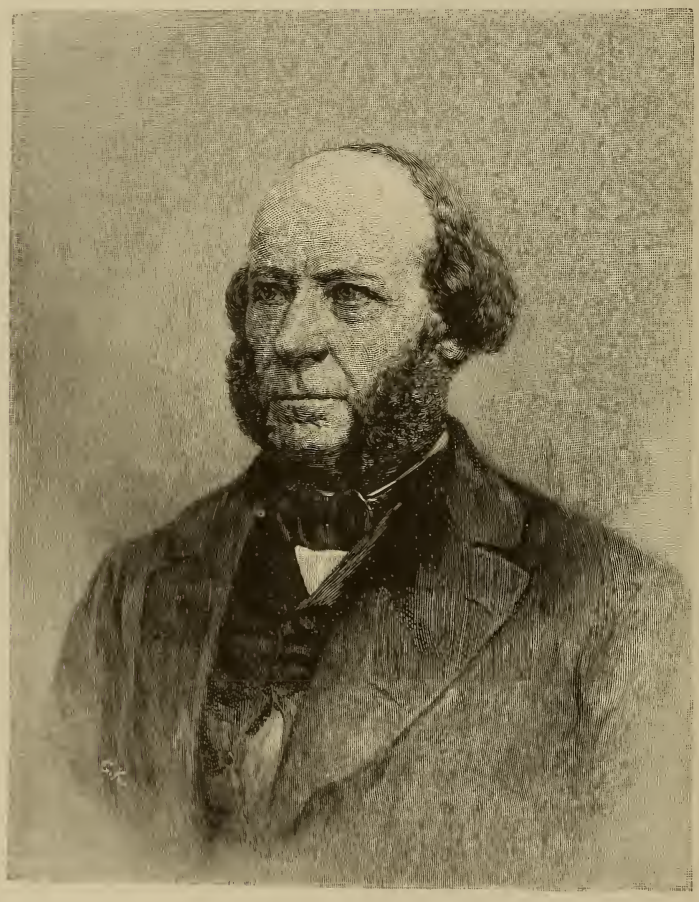
Polo in the days of the Venetian Republic; for the London tourist, in the interval between two seasons, to travel far her, and see more, than could Mungo Park in the time of George III. But do we yet realize how much more we are indebted to the workers than to the talkers for the greatness of which we boast ourselves in these Centennial years? The mechanical accomplishment of a single century has done more to destroy insular prejudice, and to bring men together in human sympathy, than the preaching of eighteen centuries. It is not statecraft, nor even military genius, that has made the United States a possibility; it is engineering ability. The bonds that hold us in indissoluble unity were forged in the workshops of craftsmen. It is the railroads, the steamboats and the telegraph that bind the Pacific States to those on the Atlantic shore; the cities on the Gulf to those that border our great lakes. It was the



J. Ericsson

FROM A PHOTOGRAPH AT THE TIME HE BUILT THE MONITOR.

ERICSSON'S HOME AFTER HIS FATHER'S FAILURE.

Pacific railroad that solved the vexed Indian question, and erased from the map the "great American desert," dividing between East and West ; just as the Trans-Caucasian railroad of Russia is transforming the wastes of central Asia into cotton fields, and the murderous fanatics of Merv and Bokhara into peaceful subjects of the White Czar. Is it not well to honor the memory of the men to whom we owe these great and beneficent changes, who have done more to realize Tennyson's dream of the "parliament of man, the federation of the world," than all the preaching of the pulpits and the eloquence of the forums ?

Chief among these men, a very king among his fellows, unquestionably stands John Ericsson ; however we test him—by natural ability, by acquired experience, or by actual accomplishment, he is first. Few men, even in his own profession, understand what was done by him ; for his work extended over so long a period that he had no sooner advanced to a new achievement than men forgot the old. If we think of the locomotive we remember George Stephenson, who died forty-one years ago, but we do not realize that we have had with us until within a year the man who contested with Stephenson the honors of the first locomotive competition in October, 1829, and who, according to contemporary accounts, surpassed Stephenson's "Rocket" with his "Novelty," steaming over thirty miles an hour. We remember the Monitor, but how few understand that the great feat of delivering that vessel within a hundred days from the signing of the contract for her, was only possible because Ericsson had previously built a hundred other vessels in which he had developed the revolutionary ideas embodied in the first turreted ironclad. These vessels include the Princeton, which is associated in memory with the melancholy accident that deprived John Tyler of two members of his cabinet, and threw the whole country

into a fever of excitement. We recall the caloric engine, with a vague impression that it was not successful. How many know that before the contest in Hampton Roads had made the name of Ericsson famous, that engine was in such extensive use that twenty-five thousand dollars were paid in a single year for royalties upon those sold, and that it opened a new era of mechanical enterprise, creating a demand for small power engines, which is still supplied by hot air engines of Ericsson's invention? We remember, possibly, that the Mechanics Institute, in 1840, bestowed its chief prize upon Ericsson for the best model of a steam fire engine, but we do not remember that as early as 1829 fires were extinguished in London with an engine of his invention, that another was sent to France, a third furnished to the Liverpool docks, and a fourth—of elegant workmanship—to the King of Prussia, Frederick William I.

We know something of Ericsson's connection with warfare on the sea, but it is not easy to realize that he twice revolutionized naval construction; first, by the ideas introduced into the Princeton, and next, by their amplification and extension in the Monitor. Still a third great change was involved in his Destroyer, which is in the line of the coming revolution in naval warfare.

Ericsson's inventions are so numerous that a mere catalogue of the most important of them, with a dozen lines of description for each, would occupy the space of this article, and would read like a page from the Patent Office report. And by inventions is not to be understood mere models, such as the ordinary inventor carries around with him to prove his insanity to the unsympathetic capitalist. Ericsson did not depend on models; his engineering conceptions were reduced to drawings, and then passed to the workshop for construction. When the expenditure involved was beyond his means, he always found men of money ready to risk their capital in the development of his ideas. Not all of these ideas were commercially successful, but the net result was the building up of large fortunes for many besides Ericsson himself—a yearly income of $50,000 resulting from a single invention which he generously gave to the friend at whose solicitation he had taken out a patent for it. A list of one hundred would include Ericsson's principal engineering conceptions; if all of his patented ideas were enumerated, this list would extend to five hundred, and the larger number would be doubled if it were to include the ideas made use of by him, and sufficiently novel to meet the requirements of the Patent Office.

Setting aside minor inventions, three distinct purposes are apparent in Ericsson's labors; first, to improve the steam engine and extend the scope of its application; next, to discover some more economical and efficient method for changing the mode of motion we call Heat into the mode of motion we call Power; third, to force the great maritime nations into declaring the ocean neutral ground, by making naval warfare too destructive a pastime to be indulged in, and equalizing the conditions of the struggle between the greater and the lesser States. On the accomplishment of this last purpose depended, in Ericsson's judgment, the future of his native Sweden. Too weak to hold her own in a contest with any great power, under existing conditions, her only sure hope of defense is in naturalizing the dominating factors of numbers and wealth by the efforts of genius stimulated by patriotism. Love of country was with Ericsson a supreme passion. In this controlling sentiment, in the traits of character derived from his sturdy Norse ancestry, and in the training and experience acquired during the twenty-three years spent in his Scandinavian home, we find the secret of that exceptional development of specialized faculties which has placed him in the very front rank of constructive engineers.

John Ericsson was a native of the province of Wermland, a tract of wooded highland lying between the chief watercourses and lakes of Sweden, on the borders of Norway, to the west of Stockholm, and on the direct line

between the capitals of these two Scandinavian kingdoms. Long the debatable ground between Sweden and Norway, its dense forests were, during the middle ages, the home of the Swedish Robin Hoods, who levied toll upon the caravans carrying tribute to the Norwegian king from the subject province of Sweden. "The bounty of God," as Duke Charles of Sweden declared three centuries ago, "has replenished the mountains of Wermland with all sorts of ores." Its wealth is in its mines, some of which have been worked for five hundred years, and its inhabitants have all the characteristics of a mining community.

HEADQUARTERS GÖTHA CANAL COMPANY.

Among these people dwelt at Langbanshyttan, in the mining district of Philipstad, at the opening of the present century, Olaf Ericsson, born in 1778. Olaf's father was Nils, and his grandfather Magnus, descended, it is supposed, from the family of Eric the Red, and his son Leif, who visited the New England coast, A. D. 1000, nearly five hundred years before the landing of Columbus on one of the Bahama islands. Leif, we are told, with his kinsmen and associates, journeyed thrice to the New England shores, and on a fourth visit, during which they remained three years, the sister-in-law of Leif bore to her second husband, Thorfinn Karlsefne, on Massachusetts soil, a son. From this first-born white son of the Bay State descended, according to John Fiske, Thorwaldsen the sculptor; so the ancestors of the Ericssons and the ancestors of the Thorwaldsens would appear to have been family connections nearly a thousand years ago.

Olaf Ericsson took to wife, in 1799, Brita Sophic Yngström, daughter of an iron-master living in Wermland, of Flemish descent. The ancestral name was Horn, a name which one of the family was compelled to change while serving as a youth in the Swedish army under Count Horn, of the celebrated historical line, the count's aristocratic ears having been offended by hearing a private soldier called by his own patronymic. The father of Brita, Jan, married a woman of Scotch descent; thus a strain of Caledonian blood was

introduced in the Ericsson family. In the case of John Ericsson we find another illustration of the theory that gifted men inherit their traits from their mother. Brita Ericsson was a warm-hearted, intellectual, spirited woman, with a firm character. She is described withal as a very handsome woman, tall and slender, with magnificent light blue eyes that deepened in color, sparkling and flashing most brilliantly, when she spoke with animation.

Olaf died in 1818, when he was forty years old; his wife Brita lived thirty years longer, and was able to tell her grandchildren, when letters came from her son John in far-off America, how an old man had prophesied to her father that in the family two boys would be born who would be renowned the world over. To Olaf and Brita were born first a daughter, Anna Caroline, in 1800; next a son, Nils, in 1802, and, finally, on July 31, 1803, appeared John, the last of the family. To the mother in her old age, when she thought of her first-born son, may have come the recollection of that older prophecy: "He also shall be great, but his younger brother shall be greater than he." The lines of the brothers' lives ran together until they were men grown, but from the very beginning the younger commenced to distance the elder.

Wealth was unknown to the Ericsson family, and Swedish country living at that time was plainness itself; but love abounded, and the mother's cheerful temper, with the father's good-humor and generous disposition, assured the blessings of a harmonious and happy home. Caroline was a child of unusual beauty, Nils was spirited and engaging, and the baby, John, a wonder to all. As a child, John was busy the day long, drawing, boring and cutting. Providing himself with pencil and paper, he would, in the early morning, run to the mines and sit there until dark, watching with deep, earnest eyes the motions of the heavy engines, copying their forms, and studying into the secrets of their motion.

The years from 1806 to 1811 were trying ones in Sweden. Industrial pursuits, including those connected with the mines, were greatly disturbed by the war with Russia, and many of the people were ruined, among them Olaf Ericsson, who was deprived of his moderate possessions and his larger prospects. His property was sold for the benefit of his creditors, and the happy home at Langbanshyttan was broken up. It was a crushing blow to the gentle-spirited Olaf, whose sensitive nature found support in his wife's more vigorous personality. In 1811, when work was resumed upon that great undertaking, the Götha Canal, he obtained a situation as foreman of a gang of workmen engaged in blasting rock along the line of the new waterways.

Despite these adverse circumstances the Ericssons resolved to give their sons a good education, and at any sacrifice to secure for them the best instructors possible. A governess was sent for; "and I remember," wrote John in after years, "with gratitude how well she taught me during the two years she was with us, 1811 and 1812." Engaged on the canal work at Forsvik was found a talented young draughtsman, who understood the art of drawing in the English style, and with a finish rivaling that of engraving. He was invited to the house of Olaf Ericsson, and received his board on condition that he should impart instruction to the two sons.

This was the turning point in the life of the lads. John especially took eagerly to instruction. Permission was granted to him and his brother to make use of the draughtsman's office established by the canal company, and when John was only eight years old his first drawing to the scale was on exhibition for the admiration of the neighborhood. He also learned to sketch maps, and before he was ten years old he had a very complete mastery of the drawing instruments with which he was to work such wonders in later life.

The father did not cease his efforts to secure for his sons the highest possible advantages of tuition. In 1813 he persuaded one of the superintending con-

structors on the canal, of high professional reputation, to give the lads lessons in algebra and architectural drawing, employing also as tutor Dr. Afzelius, a near relative of the celebrated Swedish chemist of that name. "Of course, he plagued us with lessons in the Latin grammar," writes John later on; "but I learned from him chemistry and many other things of great use to me; for instance, how to make and mix colors for my drawings out of the materials bought at the druggist's for a few cents."

Meanwhile the fortunes of Olaf Ericsson had improved. From employment as agent to select timber for lock-gates he had advanced to the post of second in the direction of the work on the canal itself, at Hajstorp Station. This change necessitated his removal to the parish of Fredsberg, on the Lefsäng, a situation whose beauty impressed itself upon the imagination of the younger son.

Still indefatigable in securing education for his sons the father applied to the court chaplain, a mighty functionary in local repute, for permission to avail himself of the service of the parish curate to teach French to Nils and John. What was more to their purpose, he persuaded the greatest mechanical draughtsman of that time in Sweden, Lieutenant Brandenburg, of the Mechanical Corps of the Navy, to teach the boys the modern art of finishing off mechanical drawings with shading. Thoroughly interested in the instruction of two pupils of such evident capacity, Brandenburg made several drawings for their guidance. These John used for models, until he became complete master of the art of mechanical drawing.

During the winter of 1816–17 he received lessons in chemistry and algebra from Professor Rash, of local reputation, who was engaged upon the canal. He was also taught field-drawing and geometry, by a German engineer officer, Captain Pentz, who was on duty fortifying the mouth of the canal on Lake Werner. He learned English from the English controller of the works at Hajstorp Station, and had opportunity to practice it with Englishmen employed on the canal.

These particulars of John Ericsson's early education are important in their bearing upon his future career. While his eagerness for instruction was exceptional, and his capacity for absorbing knowledge unusual, his opportunity for acquiring it was a rare one for that time and place—indeed, for any time and place—combining, as his study did, the practical and the theoretical. He learned thoroughly the art of presenting his ideas through the medium of mechanical drawings, without the aid of models. To a friend who once said to him, "It is a pity you did not graduate from the technological institute," Ericsson replied, "No, it was very fortunate. Had I taken a course at such an institution I should have acquired such a belief in authorities that I should never have been able to develop originality and make my own way in physics and mechanics, as I now propose to do." "The end," writes this friend, Count Rosen, in the letter from which I quote, "has proven your words true."

Except for the advantageous circumstances of John Ericsson's youth his faculties could not have received the early development which made his subsequent achievements possible; for occasions arose when his facility in handling the tools of his profession was an important element in his success. His extraordinary natural ability, having been thus developed by early training, he was able to do as much at the drawing board in a given time as two ordinary men. Without so complete a mastery of the technique of his profession he could not, at the age of twenty-six, have prepared himself in seven weeks to enter into that famous contest at Rainhill, England, for the honor of building the first high-speed locomotive; he could not have sent to sea in 1862, inside of a hundred days, a Monitor, which turned the tide of destiny and revolutionized naval warfare; he could not have furnished the Spanish Government in 1870 with

JOHN ERICSSON'S BIRTHPLACE AND MONUMENT.

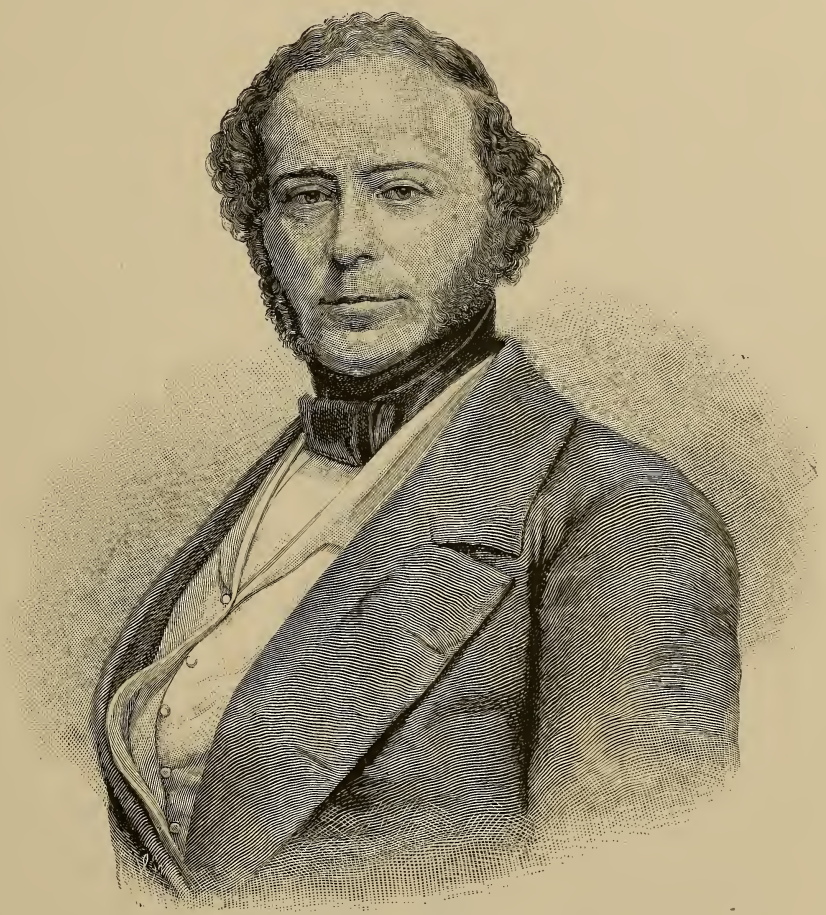
thirty effective gun-boats, within six months of the time he received the order for their construction. Nature not only endowed Ericsson with an aptitude for his chosen profession which amounted to genius, but fortune also favored him with exceptional opportunities for early training in its mysteries.

Count Platen, who had control of the works at the Götha Canal, in 1814 sent to England, at the expense of the company, two engineers, Lagerheim and Edstrom, charged with the duty of informing themselves as to the most approved methods of work in canal construction. They returned in 1815, thoroughly instructed in the best engineering methods of that time, and proceeded to drill a number of pupils, cadets of the Swedish Corps of Mechanical Engineers. The Ericsson brothers were among these cadets; John being then eleven years old and Nils twelve. Lieutenant Brandenburg introduced Captain Edstrom to his pupils, and he was so much struck with their work that he advised their father to take them without loss of time to Count Platen, then living at Holmatorp, and with them some specimens of their work.

To Holmatorp accordingly went the delighted father, with Nils and John following after. The great man was gracious, and received the lads with encouraging words. "Continue as you have begun," he said to John, as the boy looked up to him eager-eyed, "and you will one day produce something extraordinary." The lad was not one to forget such a greeting. When nearly seventy years old, writing of another who in his youth had shown him similar kindness, he said: "I always held him in the greatest esteem; he often encouraged me, and I have not yet forgotten his words. What he said to the warm-hearted boy were not empty words, and the grain he sowed has borne fruit." Even at the time he was introduced to Count Platen, the future engineer had astonished the local gossips with a saw-mill and pumping engine which he had made, "all out of his own head," at the age of ten; certainly, he had no other tools than those found in that museum of curiosities, a boy's breeches pocket. He himself

traced the first suggestion of his future career to the day when, in his seventh year, he dug a mine a foot deep and made a ladder for the use of the miners with which his childish imagination filled it.

Seeing his two sons raised to the dignity of cadets of the Mechanical Corps of the Navy, and wearing the uniform

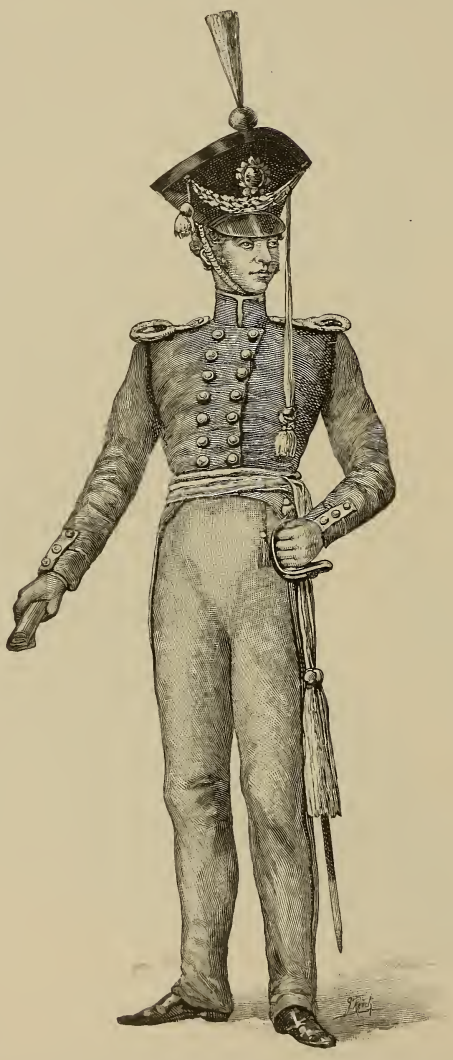


ERICSSON, ON HIS ARRIVAL IN AMERICA, 1839.

of His Majesty's service, Olaf Ericsson was a proud and happy father. His sacrifices for his children were rewarded, and their future, under the patronage of one of the most influential of Swedish subjects, seemed assured. Educated himself at the gymnasium or college at Carlstad, he fully appreciated the value of early training. As Latin, Greek and Hebrew were compulsory at the gymnasium, he must have known something of these languages. He was an accomplished penman and accountant, had excellent judgment in mechanical matters, and himself taught John before he was eleven years old how to construct an ellipse, and the use of a ball-and-socket joint; thus solving a problem the boy was struggling over in relation to his saw-mill. He explained to him also the use of a vacuum, and taught him how to raise water by combustion and the condensation of flame. He thus gave early direction to studies which were continued by his son through a career extending over three-quarters of a century of active professional work.

"I shall never forget," John said in his old age, "the joy I experienced the first time I saw the water rise in the glass cylinder at the moment my father extinguished the imprisoned flame."

Nor did the good mother fail to do her part in stimulating the ambition and training the faculties of her sons. The royal family of Sweden have always been patrons of literature, and some of its members poets and dramatists of no mean degree. The years from 1771 to 1809 include what is remembered in Sweden as the Gustavan Period—somewhat as we characterize the period of Shakespeare, Bacon and Ben Jonson as the age of Elizabeth. Ericsson's mother caught the spirit of her time. She studied with ardor philosophical, social, religious and political works. Walter Scott was among her favorites, and from her John obtained impressions concerning the imaginative arts which never wholly left him. Absorbed as he was in the dry details of mechanical construction, he occasionally found use for other metres than those of the French system of mensuration; he delighted in the sagas recording the heroic deeds of his ancestors, and when Frithiof's Saga was translated into English he hastened to present copies of the work to friends less appreciative of it than he. He has carefully filed among his papers a list, in his own handwriting, of forty Swedish songs, with a translation of their titles, including among them many songs of sentiment. He made the acquaintance of Milton, as appears from a letter, written to a friend threatened with blindness. In this he said: "My grief at your great loss is in a measure relieved when I think of what Milton accomplished after the darkness had laid its hand upon his eyes. Is there anybody with the sharpest eyesight who has given to mankind such elevated enjoyment as the blind Englishman?"



LIEUTENANT JOHN ERICSSON, JAMTLAND FIELD CHASSEURS.

We have now dug down to the root of the Ericsson family tree, and find why it is that it produced such sturdy stock as Nils and John Ericsson; for Nils, in Sweden at least, was hardly less distinguished than John, and was well known in engineering circles beyond Sweden. He rose to eminence in his profession, was the successful constructor of the Swedish system of railroads, and was ennobled. He secured a seat in Parliament, two of his sons being members of that body at the same time with him, and retired, finally, to enjoy his leisure with a com-

tortable fortune and the largest pension ever bestowed upon a Swedish subject.

The Chinese ennoble the ancestors of a man who distinguishes himself by exceptional accomplishment. The custom has its foundation in sound reason ; great men, good men, useful men, are the product of the high thought and noble aspiration, the useful labors, and the self-discipline of their ancestors. In the curious kaleidoscopic changes of character produced by the admixture of bloods, almost every pattern may appear, but none the material for which could not be found in ancestral inheritance.

While completing their course of instruction on canal work the Ericssons were busied in summer upon the canal and in the winter were transferred to the office established for the instruction of the cadets, as well as for draughting the plans for the work. In 1815, when only twelve years old, John Ericsson was employed, under the direction of his chief, in drawing profile maps and plans for use on the canal, and for filing in the archives of the canal company.

A year later, while still only thirteen years old, he was assistant to the *niveleur* in charge of the station of Riddarhagen, and when fourteen years old he was given complete charge of the Rottkilms station, where 600 of the king's troops received daily direction in their work upon the canal from the lad, who was accompanied by an assistant carrying a stool to enable him to reach the eye-piece of the surveyor's level. In his fifteenth year John was promoted to the position of assistant to the chief of the work, Lieutenant Ryding. His salary at this time was thirty crowns—$8 a month, measured by the standard of to-day, but then worth several times that sum in purchasing power. Quarters were provided him, and he was allowed traveling pay. "I had nice rooms in the company's house," he says himself, "a servant to wait upon me, and I took my meals at the same table with the chief of the works. Before I received a salary I was provided by the company with clothes and uniform and sufficient pocket money." Nils was fond of pleasure and society, and would spend his money in adorning his attractive person. His portrait shows a man of different temperament from the rugged John, whose chief delight seems to have been in his work. As occupation for his leisure, which could not have been great, John had drawn for his private use maps of the most important portions of the canal and the machinery employed in its construction. Some years later he decided to publish these, and arranged with a German officer to furnish the letter-press. Ericsson proposed to prepare etchings for the plates, and mastered the art of aqua-fortis with such readiness that he was able to begin work at once. One of the plates, the second one etched by him, was reproduced in a Swedish illustrated magazine. In acknowledging the receipt of a copy of this Ericsson said : "I remember very well the surprise of certain engravers at the sharp white edges of the pump-rods against the dark ground. The plan of rubbing these parts with a fine varnish before the plates were prepared for the aqua-fortis, which suggested itself to the beginner, enabled him to surpass the work of experienced artists."

Ericsson also invented a machine engraver, with which he was able to complete within a year eighteen plates, averaging fifteen by twenty inches each. With these his ambitious undertaking stopped, for he found that the rapid progress of mechanical improvement was rendering entirely obsolete some of the machinery he proposed to illustrate. As part of his work during the intervals of his occupation as a leveler, he executed a drawing of the Sunderland iron bridge, which Count Platen, years after, was accustomed to show his visitors, when recounting his experience with his youthful prodigy.

In other respects than this disposition to plodding industry John differed from his brother. Nils was conservative and cautious, preferring to keep to the beaten track. As he gradually gained experience in his profession, and his sterling qualities of fidelity and honesty became better known, increas-

ing responsibility was imposed upon him, and his progress to public distinction was sure, if slow. John Ericsson, on the contrary, was from the beginning searching for some new way of doing things, for some novel application of the mechanical powers which should add new forces to the world's wealth.

As a child he was impatient of routine. When scarcely out of leading-strings he made himself the victim of family discipline by stubbornly insisting upon going around on all fours, in a manner peculiar to himself, and which nursery tradition could not tolerate. When it came to learning the alphabet, he understood at once that the characters shown him were symbols, and was soon discovered busied with a sharp stick, drawing in the sand of the lake beach, bordering the little homestead, signs which he proposed to adopt as a substitute for the Swedish alphabet. The discipline to which this eccentricity thus early subjected him was but a prophecy of the opposition following him to the end of his long life, and which would have daunted a spirit less determined and aggressive. Commenting on a photograph, he once said: "The form of the forehead indicates that the man will see things as they are, and not as they ought to be, a circumstance that will remove obstacles from his path through life." It was this prophetic instinct toward things as they should be that kept Ericsson himself at war, so much of the time, with received opinions on engineering subjects. Had he been content to walk in the regulation ways, or wandered only a little outside of them, he might have plodded on his path through life to high positions, and secured the approval of professional opinion, instead of antagonizing it.

Still, his natural disposition toward revolutionary change was so controlled by sound judgment, and finally by ripened experience, that in the maturity of his powers that most eminent authority on engineering subjects, John Bourne, of London, said with equal truth and force, "that in all the attributes of mechanical genius, in originality of conception, joined with chastened sobriety of judgment, in penetrating analysis of the conditions to be fulfilled, and in skillful adaptation of means to the ends to be attained, no engineer who has appeared since the days of Watt and Murdock is comparable to John Ericsson. Every department of engineering art is stamped with the record of his triumphs."

Ericsson was, as will be seen, identified almost from his cradle with great engineering works, the Götha Canal being one of those important lines of artificial ways which connect the natural water-courses, and open the interior of Sweden to steam communication. He was brought into contact, at an early age, with the best examples of English engineering as applied to canal-work, and learned during his summers how to use practically the instruction he received during the long Swedish winters. He seemed to have found leisure with it all for boyish sports, and his active out-of-door life built up his naturally hardy constitution. He was famed as an athlete, a swimmer, and a skater, and when he was sixty years old, a gentleman who dropped in unexpectedly at a house where Ericsson was calling upon an intimate friend—Mr. E. H. Stoughton, our late minister to Russia—found him standing on his head to show how much of his youthful elasticity and vigor still remained to him. He passed through that experience which comes to most men of vigorous vitality, when the demands for bodily gratification in a measure overcome the cooler judgment, but in the end he returned to his youthful regularity and simplicity of living. Thus, with the solid foundation laid in early life, and the system which he adopted in his declining years, he was able to prolong his period of work with enjoyment almost up to the day of his death, in his eighty-sixth year, on March 8, 1889, the anniversary of the contest in Hampton Roads which made him forever famous.

In 1820, when Ericsson was seventeen years old, he reached a point in

LOCK ON GÖTHA CANAL, TROLLHATTAN FALLS.

his career where two roads met and parted. With the first suggestion of manly independence dawning in his mind he began to rebel against the career laid out for him by his friends and guardians, though before he had been more than content with it. To the home of his widowed mother came as boarders officers, civil and military, at work upon the canal, and her house was the rendezvous for the troops under their direction. Her son was brought into association with those who entertained him with stories of the great world ; the world in which the Corsican cadet of Brienne had won an empire with his sword, and the lawyer's apprentice, the royal master of the young *niveleur*, Bernadotte, a marshal's baton and a crown. Military ambition began to stir in the breast of the youth. Although he wore the king's uniform, it was not as a soldier ; he aspired to command troops, to break away from the bonds of the routine which confined him, and to lead the life of romance and adventure which, to the imagination of the young man, always lies just beyond. His good friend Count Platen protested, but Ericsson was not to be persuaded, and they parted in anger when the youth declared his determination to accept a commission as ensign in the Swedish army.

The law of foreordination and predestination was working out its results. There was experience to be acquired which could not be learned by running canal levels and ciphering out the radii of curves. The conception of a Monitor, revealing itself to the world nearly half a century later, was not an inspira-

tion but an evolution. It was the ripened result of the studies of a lifetime; prompted in the beginning by patriotic feeling, directed by the highest engineering ability and most exact mechanical training, and developed in the end by such a crisis in the history of a great nation as can occur but once in the longest lifetime. Watching the log rafts tossed in the storms upon the lakes of his native Sweden, Ericsson had implanted in his mind an idea of the principles of stability in floating constructions which was destined to germinate and grow. Another idea was needed to accompany it; that was the conception of a circular tower as the means for meeting an all-around fire. This Ericsson derived from the officer who instructed him in fortification and gunnery, to fit him for his new profession. Timby, who afterward claimed the idea of the Monitor, was not there to offer suggestions; was not even born until 1822. Further, Ericsson's experience of five years in the Swedish army gave him some instructions on the subject of artillery, which he was destined to make such effective use of in his future career as an engineer of naval constructions.

The young ensign was assigned to the Royal Field Chasseurs of Jämtland, the southern part of Norrland, one of the most barren regions of Sweden, supporting a population of less than four to the square mile, but with everything to please the imagination; beautiful landscapes, wild and imposing; immense forests of pine and fir, broad rivers, numerous lakes and lofty mountains. The station of his regiment was Frösön, near Östersund, the capital of Jämtland. John was a favorite in his regiment. He joined eagerly in the sports and Swedish gymnastics which occupied the spare time of the officers, and was soon known as one of the best shots, the best leaper and the champion wrestler. His feats of strength were noted, and the spirit of emulation sometimes carried him too far, for he suffered at intervals through life from an injury to his back resulting from over-exertion. Soon after he joined his regiment he was recommended for promotion; but his colonel, Baron Koskull, was in disgrace at court and the recommendation was not heeded.

The young Duke of Upland, Bernadotte's son, interceded with the king, winning his interest in Ericsson by showing his soldier father a military map made by the ensign. This not only secured the desired commission of a second lieutenant, but it also directed the attention of Bernadotte to the great skill of Ericsson in this work. As a result, later on, he was summoned to the royal palace to draw maps to illustrate the campaigns of the ex-marshal of Napoleon. Meantime orders had been issued to carefully survey northern Sweden, and Ericsson obtained permission to present himself at Stockholm to be examined for this work. With his early training he had no difficulty in passing the examination required. His perfect comprehension of the principles of geometry was the foundation of his clear perception of mechanical principles, and this was made so apparent that his examiners were astonished to find that he had been able to master the problems of Euclid without special study. The surveying was paid for by the piece, and as Ericsson could do double work he was carried on the rolls as two men, to avoid criticism. Altogether he contributed to the archives of Stockholm detailed drawings of fifty square miles of Swedish territory.

This was the romantic period of Ericsson's career; during it he established friendships and developed enthusiams which never left him. More than fifty years after, when his knowledge of Swedish had grown somewhat rusty from disuse, he wrote home to Sweden: "Overwhelmed with work I have not had time to write the description you ask for in my native tongue. I can think in English four times faster than I can write in Swedish, and write four times faster than I can think. As now $4 \times 4 = 16$, you will find my excuses sufficient. But this is only the case in mechanical matters, because when the language of the heart is to be used I prefer to express myself in my native

tongue. Although ignorant in all that properly belongs to mechanical philosophy when I left Sweden, I was by no means inexperienced in the language of feeling. I sometimes wrote poetry to the wonderful and enchanting midnight light of Norrland. Connoisseurs often doubted that it came from the second lieutenant and surveyor up among the mountains."

Norrland is within less than three degrees of the Arctic circle, and there the phenomenon of the midnight sun is to be seen in perfection.

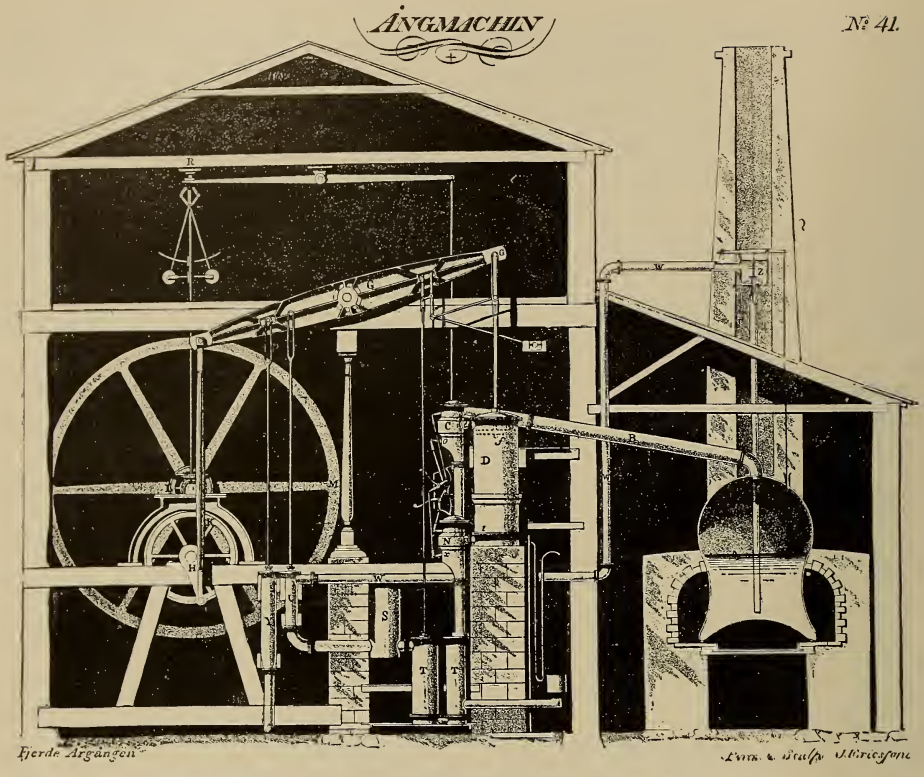
After Ericsson left Sweden his affections seem never to have rooted themselves elsewhere, and he turned toward the home of his youth always with ardent devotion. Any humble workman who had known him there was more in his eyes than the highest who might honor him elsewhere. "I am so entirely Swedish," he wrote in the midst of his Monitor triumphs, "that I cannot bear the thought that I am believed to have forgotten, or set aside in preference for some other, our beautiful mother tongue, 'the language of glory and heroes!'" The most sacred thoughts of John Ericsson's heart, and the most confidential experiences of his life are revealed, so far as revealed at all, in the Swedish letters left behind him.

Though he was a citizen of the world, and a naturalized American, his interest in his native land never ceased; indeed, his affection for it increased as he advanced in years. Yet he never visited Sweden after his departure from home in 1826. He did propose in the latter part of his life to return thither, and declared that he would rather lie under a mound of gravel in Sweden when he was dead than beneath the tallest monument that could be erected on American soil. He became interested, however, in his study of solar heat and the development of his sun motor, and was not willing to transfer himself to a region so little adapted to such studies as the high latitudes of Sweden. He needed, as he explained, to be near the vertical rays of the sun. "New York is certainly not vertically under the sun, but the rays in midsummer incline only seventeen degrees, and produce a heat scarcely two degrees less than in the tropics, thus sufficient for my purpose."

When Ericsson obtained a position securing to him an income much in excess of his modest needs, which was not until after he had reached his sixtieth year, he was constantly making gifts to Sweden and to Swedes. These appear to have attracted little or no attention in this country, but they have added a feeling of affection to the pride with which his countrymen remember him. An ancient miner sent word, through one of Ericsson's correspondents, that he had known John in his youth; immediately a draft was sent to purchase a handsome watch for the old gossip, and as one of his neighbors, "the man with the leathern apron," was subsequently found to have some vague recollections in the same line, he received one hundred and fifty crowns to "buy him a coat."

When famine pinched the Norrlanders in 1867, and collections for their relief were taken up in various countries, the total contributions from the United States amounted to 20,316 Swedish crowns. Of this sum Ericsson gave 20,216 crowns, and a subscription of 100 crowns from the Swedish minister completed the total. He sent 1000 crowns at another time to provide for the miners in his native Wermland who had outlived their capacity for work, and for the widows of deceased miners, and 10,000 crowns to the burnt city of Carlstad in the same province. He promptly responded to a request that he should furnish the money, $3000 in all, to enable the Royal Library of Stockholm to purchase a valuable collection of historical documents; he armed the first Swedish monitor of his designing with fifteen-inch guns, which are by no means inexpensive toys; he furnished at his own cost the machinery and also the plans for a Swedish gunboat, designed as a model for a fleet of coast-defense vessels, and in numerous ways his generous spirit toward his countrymen found expression.

Human nature is the same under the




AN ENGRAVING MADE BY ERICSSON IN 1821, AT THE AGE OF EIGHTEEN.

Arctic circle as in the torrid zone. Ericsson had an ardent and impulsive temperament. The glories of the midnight sun could inspire him with poetry, but the sparkling eyes of Jämtland maidens moved him still more profoundly. To one of these the young lieutenant became deeply attached. She was of an ancient and noble family; and her father was an officer of high rank. To her Ericsson was betrothed, with those formalities which in Swedish opinion at that time imposed the obligations of marriage, and were not infrequently extended to include its sanctions as well. The laws of Sweden regulating the marriage of army officers were exacting, and made impossible a legal union between a poor lieutenant and a maiden whose womanly charms and her excellent birth were her only dower. Precisely how the pair stood related to each other from our point of view cannot, at this distance of time, be determined. But custom, founded on necessity, sanctioned what restrictive laws did not recognize. The connection was subsequently dissolved, and, being free, the young woman married another Swede of distinguished reputation, and lived to old age as his wife. A son was born to Ericsson at this time, in 1824, and was adopted by his relatives in Sweden when he removed to England.

This child was well educated, and became a man highly respected, holding a prominent position in government employ. He was sent by Sweden as a Commissioner to the Centennial Exposition in Philadelphia, in 1876, and died in 1887, aged sixty-three. His widow preserves a portrait of the father, painted on ivory, in London, in 1824, by Way. It was given to her husband's mother, and represents Ericsson at the age of twenty-one. He is described as being at this time a handsome, dashing youth, with a cluster of thick, brown,

glossy curls encircling his white, massive forehead. His mouth was delicate but firm, nose straight, eyes light blue, clear and bright, with a slight expression of sadness, his complexion brilliant with the freshness and glow of healthy youth. The broad shoulders carried most splendidly the proud, erect head. He presented, in short, the very picture of vigorous manhood.

A comrade of this period, who is still living, describes young Ericsson as a noble lad, frank, faithful and honest. He had only a small coterie of intimate friends, and with these he was cheerful and charming. "He was exceedingly active," adds Major Hjärne, "always inventing, designing, constructing." King Charles John, who saw his drawings, advised him to go abroad, as his own country could not reward him as he deserved. This advice was given with more effect by one of Ericsson's brother officers, who, in a letter written forty-seven years afterward, says: "I remember the ensign, by whom I was so struck that I asked my brother officers to accept him as a comrade, and urged the colonel to secure his promotion. I could not bear the thought of this genius burying himself in Jämtland, and when I heard of his attachment for a poor girl I considered him lost to the world if he should settle there. I advised him to go to England. He at once replied that I ought not to have awakened a thought that had long slumbered within him, when I knew that his want of means made it impossible for him to realize his ambition.

"'How much do you need to start out with?' I asked.

"He answered, 'I could go in a fortnight if I had a thousand crowns.'

"I asked him to draw a note for this sum; this I indorsed and took it to the bank, and a fortnight later he had the money."

At this time Ericsson was a second lieutenant in the Swedish army. He obtained leave of absence and started for England, stopping on his way thither to participate in the festivities at Stockholm on the occasion of the birth, on May 3, 1826, of a Crown Prince, afterward Carl XV., and arriving in London May 18th. To England Ericsson carried his wonderful physique, his magnificent brain, an unusually thorough training in the technique of his profession, and a capacity for work which was phenomenal. Other possessions he had none, saving the flame engine which had excited the wonder and admiration of the Norrland garrison. The high hopes of fame and fortune founded upon this were destined to disappointment; the little engine had rendered cheerful service so long as it was fed with the splinters from the pine-forests of its native Sweden, but it did not take kindly to the sea-coal of England. So Ericsson was compelled to abandon it, but the ideas in which it originated were deeply rooted and were destined thereafter to take shape again; first in the caloric engine, and later on in the solar engine, which he has left as his bequest to the future.

Another thought destined to develop great results was present in the mind of the young Swede. Sailing with his friend Count von Rosen, in Portsmouth Harbor, their attention was directed to the fine proportions of the British men-of-war then in sight. Speculating upon the evidence these vessels gave of naval strength, so far exceeding anything that Sweden could hope to rival, Ericsson said: "I have in my mind the idea of a vessel which it is possible for Sweden to build; and which would render these wooden walls of England of no avail against her."

"Hush!" exclaimed Rosen, "if they hear you say this, they will banish you from England."

This was the voice of prophecy, and the future showed how truthfully Rosen drew the horoscope of the man whose life was to be one long antagonism with routine, and whose destiny it was to compel England twice to reconstruct the naval establishments in which were centred her pride and her hopes.

The failure of his flame engine was a bitter disappointment to the young lieutenant. Following the custom of army officers who intend to establish themselves in civil pursuits, he had obtained

leave of absence with a view to resigning. Probably the condition of hesitation and doubt resulting from his disappointment explains the breach of discipline in overstaying his leave. Neglect to obtain the acceptance of his resignation placed Ericsson in an unfortunate position. From this he was extricated by the friendly interposition of the Crown Prince of Sweden, who secured his promotion to captain, and the acceptance of his resignation, to date with this promotion, October 7, 1827—seventeen months after his departure from Sweden. The circumstances under which Ericsson obtained his title of "Captain" gave it supreme value in his eyes. He clung to it through life with great tenacity, and when asked on one occasion what title should accompany his name in a printed dedication, he answered, "Captain" and "LL.D."—the last designation being the gift of Wesleyan University; yet he was a Knight Commander of five orders, a Ph.D. of the University of Lund, a member of various Royal Academies and of numerous scientific institutions in Europe and America.

Though the expectations which drew Ericsson to England were not realized, his advent there could not have been more timely. For the new era just opening before English engineers his peculiar abilities and special training exactly fitted him. It was his habit, as I have already said, to see things as they ought to be instead of as they are, and his spirit of adventure into new regions was as indomitable as that of the Norse rovers from whom he inherited many of his mental traits. All things were to be made new, and there was need of a man ready to discard the teachings of precedent—not in the spirit of rash conceit but as one discerning clearly what lies beyond, and advancing with assured footsteps to a new goal. England's future empire was depending upon the development of the new force John Watt had placed at her disposal. Aristocratic prejudice and official opposition to innovation were barring the path of progress, but there were a few who comprehended the possibilities of the future, and among these Ericsson was chief. The list of his inventions at that time shows how clearly he perceived the lines upon which the future advance must be made.

If he did not realize his dream of checking the extravagant consumption of the earth's stores of carbon in the steam engine, he certainly did his full share to develop the capabilities of steam, to apply it to new uses, or by new and more economical methods extend its application to the old uses. It is susceptible of the clearest demonstration that Ericsson is the creator of the modern naval vessel propelled by steam, for without the application of the ideas having their origin in his busy brain it would be impossible to carry steam into battle. In the most effective type of the modern iron-clad the domination of Ericsson's conceptions is absolute; its model—speaking broadly—its machinery, its motive power, even its ordnance, all bear the impress of ideas which he put to the test of actual practice or successful experiment anywhere from a third to a half century ago.

Ericsson's caloric or heat engine was a failure only in the sense that it did not successfully establish itself in competition with the steam engine on its own ground. As a mechanical expedient it was successful, and monopolized a special field, to the great profit of those who controlled it. The steam engine is the creation of a race of engineers; when it comes to deciding to whom should be credited its several improvements, it is impossible in the wrangle of voices contending for precedence, to distinguish the one first heard. It is certain that there is scarcely one of the devices characterizing the modern marine engine, as compared with its more cumbersome and less efficient predecessors, which has not been in some measure the result of Ericsson's industrious labors and transcendent genius for mechanics.

It is said that Ericsson did not invent the screw, but it is certain that when his first screw-vessel was presented in 1838 for the inspection and approval of the Admiralty Lords—supposed to

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represent the nautical wisdom and experience of the most nautical nation in the world—it was condemned, not because it was not new, but because it was declared to be impracticable. Ericsson did not discover the screw, because it had often been suggested and experimented with under various forms, but he did work out successfully the problem of screw propulsion, apply the screw to forty-one vessels on this side of the Atlantic before it had passed beyond the stage of experiment in England, and finally compel the Privy Council of England, by granting an extension of his patent, and the Admiralty, by paying him an award for its use, to acknowledge that he certainly did invent a screw. When marine wisdom shall have settled, by concurrence of opinion, what is the best form, and what the best application of the screw, it will be time enough to consider how much advance has been made upon the ideas of John Ericsson.

If we accept Herbert Spencer's definition of altruism as being "all action which in the normal course of things benefits others instead of benefiting self," then was John Ericsson one of the most consistent disciples of this philosophy. Throughout life he was accustomed to sacrifice himself for his ideas, and if in those ideas a distinctly philanthropic intention was not always discernible, they were unquestionably directed by high purpose toward improving the conditions of the race. Ericsson's Monitor would not be ordinarily classed among benevolent institutions; yet the original inspiration to his studies in naval defense was one of the highest and holiest of all impulses—the love of country. He sought to protect his native land against foreign aggression, and especially against the encroachments of Russia, whose hostility to Sweden was among the most vivid and painful recollections of his early youth. "My object in laying the matter before the Emperor Napoleon was," he says, "to cause the destruction of the fleets of the hereditary enemy of my native land. Strange to say, no sooner did the communication reach its destination than news came that the fleet at Sebastopol had been voluntarily consigned to those subaqueous regions which I had had in view. I ceased to labor in the matter until our civil war broke out, when I took up with great enthusiasm and finally elaborated some points of detail, cautiously waiting to move, however, until England and France should by overt act espouse the cause of our enemies—a cause which involved the perpetuation of the bondage and the firmer riveting for another century of the shackles on four millions of persons whose only crime was their color; the inevitable consequence being that at the end of that century this fair portion of our planet would have contained some forty millions of bondmen."

(*To be Concluded.*)

ERECTED ABOUT 1890.

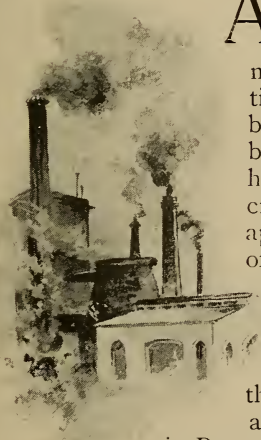
BLAST FURNACES AT PITTSBURGH, PA.

ERECTED PRIOR TO 1880.

# HOW IRON IS MADE.

*By John Birkinbine, Past Pres. Am. Inst. M. E.*

First Paper.



AN attempt to describe in detail how iron is now made would cover practically all of the steps by which this special branch of manufacture has advanced from the crude and most ancient appliances to the details of modern practice: for it is surprising how closely the methods which are still employed in the heart of the Chinese and Japanese empires, in Borneo, in Africa, in India, and in parts of South America, correspond with the records of early iron production in Western Asia and Europe. The ethnologist can in this find interesting studies, determining whether the ancient methods have been carried from one nation to another, and if so, by what means of communication; or whether independent empirical investigation of nature's secrets has resulted in different peoples, removed from each other by distance, language and traditions, accomplishing similar results by nearly similar means.

North American history gives no authentic record of the use of the earlier processes, for the aborigines seem to have been ignorant of iron manufacture, most of their implements, weapons and tools being of stone or copper; and, except for the uncertainty surrounding the history of the first attempts to make iron toward the middle of the Seventeenth Century, the statement might be made that none of the primitive methods of iron production were attempted in what is now the United States, or possibly in the northern portion of our continent. It has been claimed that as copper served the purposes of the American aborigines better than iron, there was little to encourage the production or use of the latter metal.

A little over 300 years marks the interval between the present time and the reputed discovery of iron ore in North America, the first recorded shipment of which was in 1608, but the earliest attempted, known use of the mineral locally was in 1622. However, successful practical iron manufacture in the United States has a history of less than two and one-half centuries, and as European methods were introduced and European specialists were employed, American iron manufacture did not pass through the primitive methods of open heaps, low mud furnaces (some of which antedate the Christian era), or even the Osmond furnace or the "stückofen" described by Percy. It is probable that all of the iron produced in America was obtained either from blast furnaces or modified Catalan forge fires, and that these were actuated by blast supplied by other than animal power. While today it may be possible to find in various portions of the world all methods of iron production, from the open heap to the modern blast furnace, blown by all types of pneumatic apparatus, ranging from the skins of animals sewn into bags and trodden by the workers' feet, or the tubes of bamboo, whose pistons are alternately actuated by the arms or legs of attendants, to a massive blowing engine driven by steam, in the area covered by the United States no appliances are known to have been used cruder than are represented by the forge

20 YEARS OLD. A COKE FURNACE AND A CHARCOAL FURNACE. 40 YEARS OLD.

or blast furnace to which air was supplied by wooden or leather bellows, actuated by a water wheel; or the trompe, into the tube of which a column of falling water drew air and forced it under pressure from a wind box. Each of the various forms of furnace or forge, and the blast apparatus used, have been described in works upon metallurgy, and a repetition of facts which are generally accepted as historically correct is unnecessary; therefore, beyond the presentation, as showing progress achieved, of some details which concern the history of iron manufacture in the United States, or comparison of plants or processes now or lately in use, these papers will treat more of how iron is made than as to how iron was made.

The blast furnace of to-day differs from that first erected in America in size and equipment, but its general interior form and the process connected with it are practically the same. In design, a blast furnace was then, and is now, a structure built up of incombustibles, with an opening extending from the bottom to the top, lined with special refractory material. In form, this opening represents two frustra of cones, placed base to base, the lower frustrum resting on a short cylinder. This cylinder is the "crucible," or "hearth;" the flaring sides of the lower frustrum form the "bosh," and the taper of the upper frustrum, the "inwall." The crucible is pierced with openings for the "tuyeres," admitting air under pressure to support the combustion of the fuel, and others through which the molten iron and cinder flow. Into the top of the "stack," fuel, ore and flux are fed in proportions to secure the best results, at such intervals as will keep the furnace filled. But the large furnace of the present time, with a bosh diameter reaching 22 feet, and a height of 95 feet, overshadows its prototype whose greatest interior diameter was 8 feet, and total height 30 feet. The modern steam blowing engine, supplying 20,000 cubic feet of air per minute through massive fire brick stoves in which it is heated to 1200° Fahrenheit

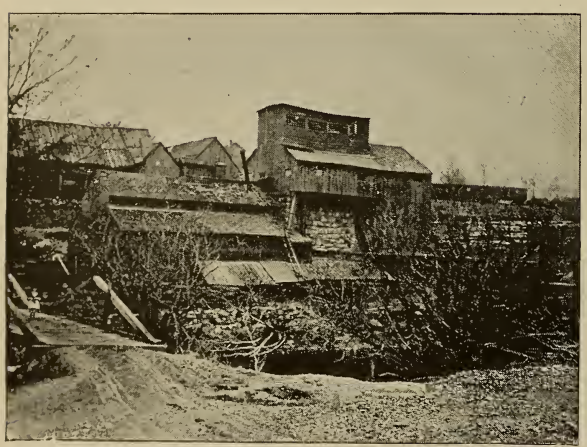
or more, and driven into the furnace at a pressure of ten pounds per square inch, is a giant in power, yet occupying no more ground space than the water wheel and the wooden tubs actuated by it required, which delivered one thousand cubic feet of air per minute into the older furnace at a pressure of one-half pound per square inch.

The trim iron shell, carried on iron columns, allows the modern furnace stack which produces three hundred tons of pig metal per day, to stand on the same foundation which was required by the greater mass of masonry of the olden furnace producing only three tons per day. The storage room required for raw materials is nearly the same for a large modern plant which obtains its ore, fuel, and flux regularly by railroad cars, as it was for an ancient charcoal furnace, to which all supplies were hauled by wagons drawn by horses or oxen, and for the supply of which great stocks of charcoal, and often of ore, had to be collected and stored over the season when coaling could not be prosecuted or materials hauled over bad roads. In fact, if the extensive stabling accommodation for hundreds of mules or oxen are considered as an essential feature (for such they really were) of the iron plant, the space occupied by the buildings of a charcoal furnace of a century ago, exceeds that of a coke furnace which now adds as much to the country's output of pig iron in three days, as the old furnace would make in a year.

PINE GROVE, PA., CHARCOAL FURNACE, BUILT IN 1771. REMODELED IN 1878.

To illustrate locally the development of the American pig iron industry, the following is excerpted from a presidential address which the author delivered in 1892 at a meeting of the American Institute of Mining Engineers: "Southwest of Pottstown, Pa., the Warwick furnace was built in 1738 and remained active for one hundred and thirty years;

during which time it maintained a high reputation for its product of pig iron and castings, some of the latter being munitions of war used in our struggle for independence. The present Warwick furnace at Pottstown has borrowed the name of the old plant, but its successful management has given it a glory of its own. The old Warwick furnace was known in its day as one of the largest in the country, its height being 32 feet, and its bosh varying from 7½ to 9 feet in diameter in different campaigns. This old stone stack, blown with wooden bellows, produced from 25 to 30 tons of iron per week, sometimes reaching the then extraordinary output of 40 tons.



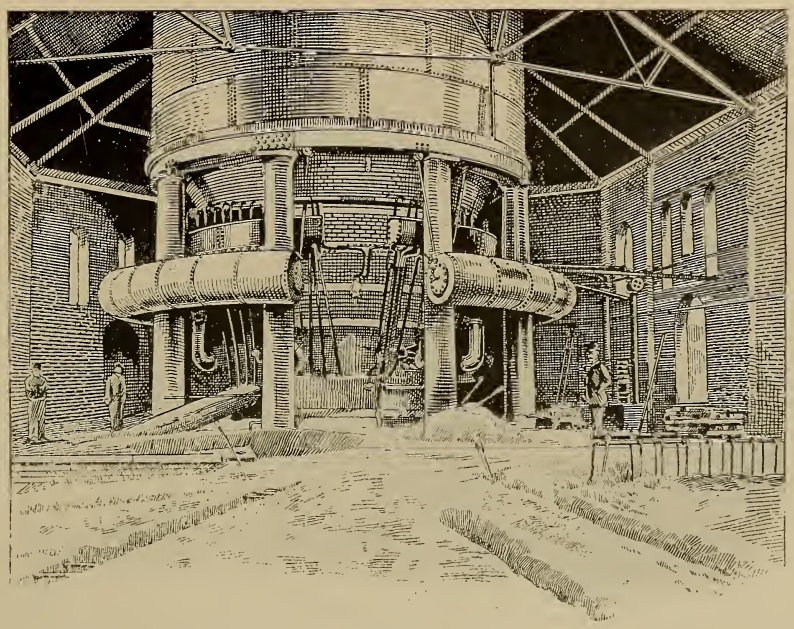
A NEW ENGLAND CHARCOAL FURNACE.

its present namesake, an iron shell supported on columns, with modern equipment, has a height of 70 feet, and a diameter at the bosh of 16 feet, has been averaging 1100 tons of pig iron per week. * * * * *

"We may in imagination look back to the time when the Schuylkill Valley, now teeming with industries, traversed by railways and covered with population, was sparsely inhabited by settlers who had made scattered clearings in the wooded area, and picture to ourselves the pioneer iron manufacturers, struggling with the difficulties attendant upon an initial enterprise. We can almost hear the melancholy groan of the great bellows, receiving its power from a slowly moving water wheel, or the thud of the trip hammer as it pounded the loupe or bloom, and see the numerous teams bringing charcoal and ore, or hauling away pigs, blooms or bars. As the shifting scene approaches the present era, the forests disappear before the axe and cultivated fields replace the woodlands, in the diminishing area of which colliers are converting the wood into charcoal to supply the iron works; new mines are opened to meet the ever increasing demand for raw material; towns grow up into industrial centres; and a canal system is established as a convenient method of transportation. Although this development appeared rapid at that time, it was only within the past half century that greater strides were taken. The Schuylkill Valley boasts of one of the earliest extensive railroad systems; and nearly simultaneously with the employment of this method of transportation came the liberal exploitation of the coal fields, the use of mineral fuel, the application of hot blast, and the utilization of steam power at iron works. Great as these changes were they have been surpassed in turn by the history of the last twenty years, in which technical investigation has aided practical skill in obtaining better and larger results than had been believed to be possible."

The above excerpt referred to the development in a small section of eastern Pennsylvania, a State which, though now producing one-half of America's total, has no definite record of making any iron until 1716, although Mr. Swank credits Pennsylvania with producing this metal in 1692, in which year was published the statement in quaint verse:

"A certain place here is, where some begun
To try some Mettle and have made it run,
Wherein was Iron absolutely found.
At once was known about some Forty
Pound."



CRUCIBLE AND BOSHES OF A BLAST FURNACE.

What kind of iron this was, or where or by whom it was produced, is uncertain. From an output of forty pounds in 1692 the industry grew in Pennsylvania until, in 1892, just two centuries later, a total of 4,193,805 gross tons of pig iron were produced in that State.

Another instance of development may be found in an extract from the report of the president of the Illinois Steel Company, for the year ending December 31, 1893, which says: "We received during the year 1,283,428 tons of raw material. We shipped during the year 422,784 tons of finished product. The total number of cars of material hauled was 61,714. We paid in wages and salaries $3,230,885.63, and employed an average number of 4264 men per day. Our purchase of miscellaneous stores and supplies, other than raw material, amounted to $898,719.69." This, too, for a year when parts of these great works were entirely idle, and other parts were operated for but a portion of the time, owing to restricted orders. These figures will be the more notable when it is remembered that no iron was made in Illinois or Wisconsin until 1839. For the past five years the consumption of pig iron in the United States has ranged between seven and nine million tons, the former representing the reduced demand in the year 1893 which depressed times encouraged, thus cutting down the domestic production and increasing accumulated stocks.

There is still a small amount of iron produced in the United States in bloomaries or forges, but the large consumption of fuel and waste of ore prevent these open fireplaces from being used, except to supply a limited quantity of special metal from ores rich in iron, "brought to nature" and "louped" in a charcoal fire. Beyond the addition of pipes placed in the chimneys of the fireplaces, in which the blast is heated before passing into the fire, and some minor features of construction, these "bloomary" fires are a reproduction of the ancient form known as the "Catalan" forge, from its use in Catalonia, a portion of Spain.

In 1892 Mr. W. H. Adams located the site of one of the earlier American iron works in Spottsylvania County, Virginia, and at considerable expense

PART OF RAPPAHANNOCK FURNACE, VIRGINIA, ONE OF THE FIRST IRON FURNACES BUILT IN AMERICA, EXPOSED BY EXCAVATION.

excavated sufficient of the accumulated debris to expose portions of the structure of the Rappahannock furnace, erected in 1714. Mr. David Williams of New York secured excellent photographs of the ruins of this tombstone of former activity, two of which are here presented. This furnace stood close to the bank of a small stream which furnished the necessary power, considerable grading being done to provide for the operation of the furnace, etc. Mr. Adams states that he found the furnace masonry nearly intact, almost as it was left by the last workmen 160 years ago. A large black walnut tree, growing from the mouth of the furnace, held the heavy walls in place with its roots. The furnace walls and top were made of a special imported brick.

RUINS OF RAPPAHANNOCK FURNACE, VIRGINIA, BUILT IN 1714 (?)

Scattered throughout the older settled portion of the United States, remnants of iron works are found, none of which can lay claim to being ancient, for few of the ruins exceed a century in age. Of some, constructed since 1800, nothing remains but a cinder heap, overgrown with a vegetation which kind nature has provided for such apparently unproductive soil. In other instances, crumbling furnace stacks, often with large trees growing from the debris, or a mill dam or race, or a few weather beaten timbers mark the sites of former activity. Of others, only the good name, won by superiority of product, or a few castings, bearing some special legend, recall the fact of their former existence. There are, however, some well-preserved relics of "ye olden time," one of the most notable being the "Cornwall charcoal furnace," at the Cornwall ore hills in central Pennsylvania, which was built in 1742, and was active until about 1887. The original furnace stack and some of the old brown stone buildings still stand, although many changes have been made. But this can be considered as the furnace whose activity covered a greater inter-

MAKING CHARCOAL FOR A BLAST FURNACE IN SOUTHERN OHIO.

val of time than any other in America, and as the best preserved of the older iron works. "This old furnace passed through various changes in machinery equipment, from the leathern bellows to the wooden and, later, iron blowing tubs, driven by water-power, its last campaigns being made with a steam engine supplementing the water wheel; but it was always blown with cold blast, and worked with an open top, and stone hearths only have been used."

One of the exhibits at the World's Fair was a modest tea kettle, referred to at length elsewhere in this number, credited with being the oldest casting now extant from an American iron works. This casting was exhibited by the city of Lynn, Mass., near which Mr. James M. Swank locates the first successful iron works, ultimately consisting of a furnace, forge and foundry, in operation in 1645.

Mixtures of from 18 to 40 parts by weight of coke, anthracite coal, or charcoal, 33 to 58 parts of prepared iron ore, and 2 to 30 parts of limestone represent the proportions of the ingredients which are required to produce most of the pig iron made in the United States. There may be instances where the minima are temporarily slightly below this, but only where exceptionally pure ores are supplied, and excellent management prevails; per contra, lean ores, inferior fuel or limestone, or inefficient direction may cause greater maxima. The above are the mineral substances fed to a blast furnace. But in addition, there is driven into it, through the tuyeres, a volume of air to support the combustion of the fuel which approximates the combined weight of ore, flux and fuel. With the exception of a few empirical campaigns the use of mineral fuel has always been accompanied by the introduction of heated air into the furnace hearth. At first the air was heated to 300° or 400° Fahr.; then the temperature was increased to 600° or 900° Fahr., and in late years the employment of regenerative stoves has encouraged the use of air raised to 1200° and 1400° Fahr., the increased temperature of the blast permitting a material reduction of the amount of fuel consumed. The source of metal is the

iron ore, and the proportion of foreign ingredients, particularly those of an earthy character, which are associated with the oxide of iron in the ore, influence the quantity of limestone necessary as a flux to carry off these impurities in the slag. Sulphur in the iron ore or fuel, and the proportion of incombustibles in the latter, demand additions of lime to the furnace charge. Some calcareous ores being self-fluxing, reduce the necessary lime "burden."

The limestone used is either carbonate of lime or a combination of the carbonates of lime and magnesia (dolomite), and the quantity required is also dependent upon the silicia or other ingredients intermixed, the fluxing capacity of the stone being reduced if it must be utilized, in part, to carry off its own impurities. Under similar conditions the greater the percentage of iron in the ore, the smaller will be the amount of fuel required, except as the physical characteristics of the mineral or its preparation, or as the equipment and management of individual furnaces affect this, for if ores are fed to blast furnaces in proper condition, and if the operation of smelting is assisted by approved equipment and direction, a material reduction of fuel is possible.

ANOTHER NEW ENGLAND CHARCOAL FURNACE.

The general dense character of magnetites in which iron and oxygen are found in the proportions of 3 to 4, makes this class of ore more difficult of reduction than the hematites, which are usually either more porous, or more readily disintegrated, and in which two parts of iron are combined with three parts of oxygen. The comparative reducibility of iron ores is influenced by their physical conditions, by the fusibility of the gangue, and by the manner in which this and the iron oxide are intermixed. When practically free from gangue, magnetite furnishes the ore richest in iron, followed in order by the red hematite, brown or hydrated hematite, and spathic or carbonate ores (in the latter, protoxide of iron is combined with carbonic acid) ; and although such purity is unusual, large quantities of iron ore have been obtained in this country close to the theoretical limit of 72.4 per cent. of metallic iron for magnetite, 70 per cent. for red hematite, 60 per cent. for brown hematite, and 48.3 per cent. for carbonate ores. The average of all the iron ores mined and smelted in the United States, however, approximates 53 per cent. of iron, and this average yield is obtained only by carefully sorting, washing off argillaceous matter, roasting to eliminate carbonic acid, sulphur or water, and concentrating by jigs or separators fullyone third of the iron ores fed to blast furnaces.

In addition to the ores extracted from the earth, other materials also, from which metallic iron is obtained, are charged into blast furnaces. These are slags resulting from the conversion of pig iron into wrought iron, and residuums from the calcination of ores carrying considerable amounts of sulphur and zinc, etc., which retain a large percentage of iron. The census figures for 1890 show that of the material fed to the United States blast furnaces 93 per

cent. was iron ore, and 7 per cent. mill cinder, residuum, etc. The larger proportion of such material is the cinder resulting from the conversion of pig into wrought iron, or from heating iron or steel, and as this cinder carries off much of the impurities from the metal, it may be considered, for the purpose used, a rich but impure iron ore. But the percentage of deleterious ingredients contained in mill cinder is often less than that found in iron ores largely used. The prejudice existing against pig iron in the production of which mill cinder is used in part may be unfair, unless a knowledge of the actual compositions of the "cinder pig iron" and the "mine pig iron" with which it competes are both known. "Blue billy," a finely comminuted oxide of iron resulting from the roasting of the iron pyrites used as raw material for the production of sulphuric acid, is also employed as an iron ore, and the unique deposits of "franklinite" in New Jersey, over which there has been expensive litigation, to determine whether its tripartite composition entitled it to be recognized as an iron ore, zinc ore, or manganese ore, yields, after calcination to extract zinc, a clinker from which spiegeleisen or manganiferous pig iron is obtained.

About three-fourths of the pig iron made in the United States is obtained by using as fuel in the blast furnaces coke produced from bituminous coal. Formerly much of this coal was charged in a raw state, but at present raw coal is only employed as a mixture on a limited scale with coke where satisfactory non-coking bituminous coals are cheaply obtained. A considerable portion of the pig iron output of this country was lately produced with anthracite coal as fuel, and this class of mineral fuel is still largely used; but, as a rule, coke is mixed with anthracite to permit of more rapid driving of the furnace and to decrease resistance to the blast. The open, porous character of coke encourages rapid combustion, whereas the dense character of anthracite permits of the oxygen introduced into the furnace through the tuyeres attacking the exterior incandescent surfaces only. The extent to which the advantage of the greater surface of coke could be overcome by employing smaller sizes of anthracite is an unsolved problem, for although experience has proven that as the size of anthracite was reduced better results followed, this reduction of size can only be secured by breaking up large coal at considerable cost, and waste, or small sizes, which are in demand for many commercial and for household purposes, must be purchased at an advance over the price for the sizes generally employed in blast furnaces, an advance in most cases sufficient to offset the cost of coke for mixture. Besides this, an increase of power to overcome the resistance of the stock in the furnace would be demanded for the smaller coal. Formerly when the top or tunnel-head of the blast furnace stack was open, the escaping gases were there ignited, and the anthracite, charged in large lumps, was splintered by a sudden rise in temperature. But the present practice, with tunnel-heads closed, approves keeping the top of the furnace at a low temperature, and lumps of coal, being gradually heated, are less apt to be broken up.

The use of charcoal as a fuel for smelting iron is restricted by the available supply of wood which can be collected at points where suitable ores are obtainable, or from which the product can be advantageously marketed. This was the only fuel successfully employed in iron production in the United States up to 1839, and more iron was smelted by the use of this than of any other fuel until 1855, when it gave precedence to anthracite; but more iron was produced with charcoal than with bituminous coal and coke as late as 1868. Hence, anyone now between the ages of sixty and seventy years who was, in childhood, familiar with the iron industry, can well remember when charcoal was the only fuel used for smelting iron ores in the United States. He or she had reached maturity before more iron was made with anthracite coal than with charcoal, and had lived over forty

years before the fuel which now produces 74 per cent. of American pig iron had become ascendant. In the older practice, when the charcoal was all made in open heaps in the woods and fed to small blast furnaces, into which the air was blown at atmospheric temperatures, an average of at least six cords of wood were converted into charcoal for each ton of pig iron made, but present economies in the use of kilns for charring wood, the employment of hot blast, and rich ores fed to larger blast furnaces permit an average of from $2\frac{1}{2}$ to 3 cords of wood being sufficient for each ton of metal made, and individual cases are noted where but two cords of wood per ton of pig iron is required. A considerable amount of charcoal is produced in retorts where by reason of the external firing, an increased yield per cord of wood is obtained, and much of the charcoal so made is sold to blast furnaces. If retorts were operated so as to supply entirely a blast furnace plant with charcoal of the quality desired, it may be possible where rich ores are employed to reduce the consumption of wood to less than two cords per ton of pig iron made, but at present writing there are no American charcoal blast furnaces which depend entirely upon retort-made charcoal.

The rapid denudation of convenient forest areas, and the cultivation of much of those cut over, made many of the older sites for charcoal blast furnaces unfavorable for continued activity, and the changed conditions of trade relegated others to the ranks of idleness, so that the number of charcoal blast furnaces is now smaller than ever before and yet improved methods permit of an annual output exceeding 600,000 long tons of pig iron, which is more than the greatest production when the furnaces were treble the number at present active. The use of bituminous coal following that of anthracite, the iron industry was relieved of anxiety as to a sufficiency of fuel, which dependence upon charcoal had occasioned. It is doubtful whether, even with all improved appliances, and with careful reforestration, the United States could produce, advantageously, one third of its present output of pig iron, if charcoal were the only fuel available for smelting purposes.

Charcoal is even more porous than coke, and being freer from ash and sulphur is a still better blast furnace fuel than coke. A series of interesting analyses made in Sweden show, however, that charcoal made from some woods may be higher in phosphorus than some approved cokes carrying a modicum of this element. Various qualities of charcoal, coke and anthracite differ in their specific gravities, but in general terms, a given weight of coke will occupy double the space that the same weight of anthracite will require, and a ton of charcoal in a blast furnace will fill twice as much space as a ton of coke, or four times as much room as an equal weight of anthracite coal. The denudation of convenient timber which the supply of a plant of moderate size demands, or the expense and loss in transporting this bulky, friable material, interferes with the employment of charcoal on a liberal scale, and restricts the size of furnaces using this fuel; but the handling and transportation of charcoal has been carefully studied in various sections of the country, and it is hauled long distances in specially constructed railroad cars at low cost.

The advance in output per furnace, as above referred to, is not peculiar to those using charcoal, but applies equally to those using mineral fuel; in fact, the greater size of the latter make the improvement appear more marked than in the charcoal blast furnaces. As the difficulty in maintaining a fuel supply for a large plant restricts the size of a blast furnace operated with charcoal, it also prevents assembling a number of stacks at a given location, but no such embargo controls the size or number of furnaces using mineral fuel; consequently in all important plants where from three to nine blast furnaces are grouped, the stacks are of large dimensions. This refers to furnaces operated under one management and located close together. There is an undoubted advantage in the costs

for labor, supervision and the proportion of fixed charges at a plant consisting of several furnaces. Some of the larger corporations interested in the production of iron and steel embrace a number of furnace plants, located at different points, each having its own management, but all operated from a central supervising office, which attends to the purchase and sale of material, keeps accounts and carries on other features of administration. Instances of such combinations are the Illinois Steel Company, having nineteen furnaces located in four distinct plants in Chicago, and one at Milwaukee, Wis., these plants supplying the material for the steel works of the company. As a producer of pig iron for sale, however, the Tennessee Coal, Iron and Railroad Company, operating seventeen furnaces in five plants in the State of Alabama, and two in the State of Tennessee, outranks the Illinois Steel Company, although the former produces a much larger quantity of metal.

In recording the number and output of blast furnaces, the American Iron and Steel Association, whose statistics are accepted as the most reliable, divides the plants according to the fuel used, and also according to States and districts. These divisions are solely for convenience, and for giving detailed information ; for the fuel used in a given furnace does not necessarily indicate a different basis of construction, more than does the location, except in so far as the size of plant, strength, and capacity of equipment, etc., are modified to meet the local requirements. A furnace using charcoal can, if its equipment is powerful enough, be run on coke or on anthracite, and *vice versa*, although, to secure the best results, minor modifications are not to be discounted. The writer had an opportunity to practically demonstrate this in 1877, by an experiment made at the Pine Grove Furnace, Pennsylvania, during an interval between two seasons' supply of charcoal. The furnace stack, although small, was well equipped. The old structure built in 1771 had lately been increased in height, the wooden blowing tubs, which had for decades, through the intervention of a "tired water wheel," delivered a weak blast of air, had given place to a powerful steam blowing engine and boilers ; the open top or furnace tunnel-head, which had served for generations as a beacon to the valley, was closed, and brief intermittent illuminations occurred only when the bell closing the furnace mouth was lowered to drop a "charge," and the fore-hearth from which molten iron had been ladled was destroyed to permit of using water-cooled dam, tymp and tuyeres ; in fact, an attempt was made to modernize an old landmark.

After the supply of charcoal on hand was exhausted, the campaign was continued with coke ; then, by reason of a short supply of coke due to a strike, coke and anthracite were mixed ; then all anthracite was charged, followed by other mixtures of coke and anthracite, all coke, and finally again charcoal. Careful records kept during these experiments permitted of drawing the conclusions forming the basis of some of the statements presented in these papers. These records showed that larger outputs and lower fuel consumption per ton of product were obtained when using charcoal than when coke was charged, and that, as anthracite coal replaced coke, the output fell off, and the fuel consumption increased. The pressure of air necessary to operate the furnace was also augmented as a larger portion of anthracite was used, and the greater amount of ash and sulphur in the mineral fuel demanded more limestone as flux than was required when charcoal was employed.

# PRIMITIVE TYPES OF THE SUSPENSION CABLE AND TOW-LINE.

*By W. F. Durfee.*

THE idea of twisting fibres together in order to obtain the advantages of their aggregate strength, was probably suggested to the primeval man by the various climbing plants that naturally entwine themselves, for the first ropes were certainly made in the vast forest rope factories of Nature. The tow-line is doubtless the earliest, as it is still the simplest, application of a rope for the moving of material. Hitched to a floating log, the genesis of all water craft, canoe or sledge, it was used before history learned the art of writing, or mankind the art of reading. In early times, when the chief business of mankind was conquering and being conquered, ropes occupied a most important position in the primitive ordnance of the warring nations. The bow-string, the sling and the funicular springs of the catapult and balister are examples of an indispensable use of ropes in ancient machines of war.

All our funicular machinery is but a development of the "tow-line," whose chief function is to pull some object with a view of changing its position. Originally the tow-line was used to move bodies horizontally, but it was soon found that it could be employed for pulling them up inclined planes, such as hills upon land and steep rapids in running streams, and from its use in that way to hoisting weights vertically was but a natural transition.

The tow-line was combined with the suspension cable as a means of crossing streams in the mountains of Hindustan at a very remote period. The suspen-

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FIG. I. A ROPE BRIDGE IN THE HIMALAYAS.

sion cable, often several hundred feet in length, was made of twisted fibres, or slender stalks of climbing vines. This was solidly secured to large trees or masses of rock on the banks of the chasm to be crossed. On this cable a wooden block, grooved underneath, was placed, suspended from which was a small, rude platform, or, at times, a simple loop of rope, for the passenger or baggage. The wooden block with its attached load was pulled across the chasm in either direction by a tow-line attached to the block. This rude contrivance is the genesis of the most refined aerial ropeways of the present day, and of the suspension bridge also, which is, in a crude form, of very great antiquity.

FIG. 2. A MODERN EXAMPLE OF TOW-LINE AND SUSPENSION CABLE.

When the Spaniards first visited Peru, they found suspension bridges which could be traversed by men and burdened animals. Some of these bridges were of over two hundred feet span, and were formed of half a dozen cables of twisted osiers, stretched from bank to bank, and passed over wooden supports. These cables were bound together by smaller ropes, and were covered with a layer of bamboo which formed a support for the roadway.

A very common modern application of the tow-line and suspension cable is represented by Fig. 2, in which they are employed to suspend and convey "the washing" across the "chasm" above the back yards of city tenement houses. Another instance of the survival of the ancient idea of suspension cable and tow-rope is found in the combination — almost universally used on sailing vessels—of the jib stay, the jib with its wooden hanks, and the jib halyards, as shown in Fig. 3. The suspension cable and the tow-rope are now common expedients for the transportation of ores in mountainous districts in all parts of the world. Fig. 5 shows a combination which was in use in Colorado prior to 1870, it being one of the earliest installations of the kind in the United States. The suspension cable was stationary, and formed a continuous track for the trolleys of the mineral cars which, descending loaded, drew up the empty cars on a parallel suspension cable by means of a tow-line, not shown in the sketch. This tow-line was attached to machinery which controlled the speed of the cars.

Fig. 4 is a cross section of a railway with a single-track suspended rail, this rail taking the place of a suspension cable. It was proposed in 1824 by Mr. H. R. Palmer, C. E., an English inventor. The cars, or panniers, were designed to be hung from truck wheels which were intended to run upon the upper surface of a suspended rail designed to be supported by posts at frequent intervals. The cars were to be pulled by horses by means of a tow-line of such length as to permit them to travel on the more or less irregular surface of the ground. Mr. Palmer pub-

lished a well illustrated pamphlet descriptive of his invention, the frontispiece representing an extended landscape with his railway in operation in the middle distance. A portion of this is reproduced in Fig. 8. A remarkable feature of Mr. Palmer's plans is his proposal of what is now known as the cantilever bridge, in regard to which he says: "The frontispiece exhibits one design for the passing of a river. It is partly supported by struts and partly by wrought-iron suspended bars, which extend from the abutment to the end of an inverted king post in the centre. When height is not required for navigation, this becomes a very economical construction." Schemes for similar railways have been brought forward from time to time, but none of them have ever survived an experimental youth. Just how their promoters intended to arrange frogs, switches and crossings to satisfy the complicated conditions of the yard-room required at the terminals of a line having an extensive traffic, has never been made clear.

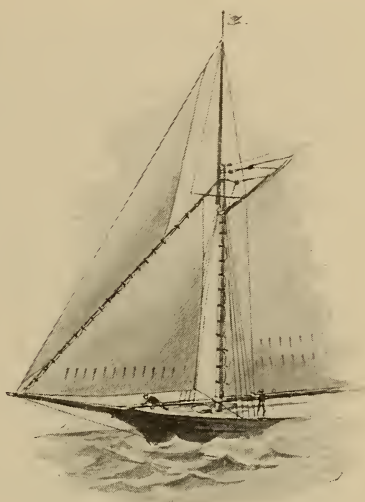
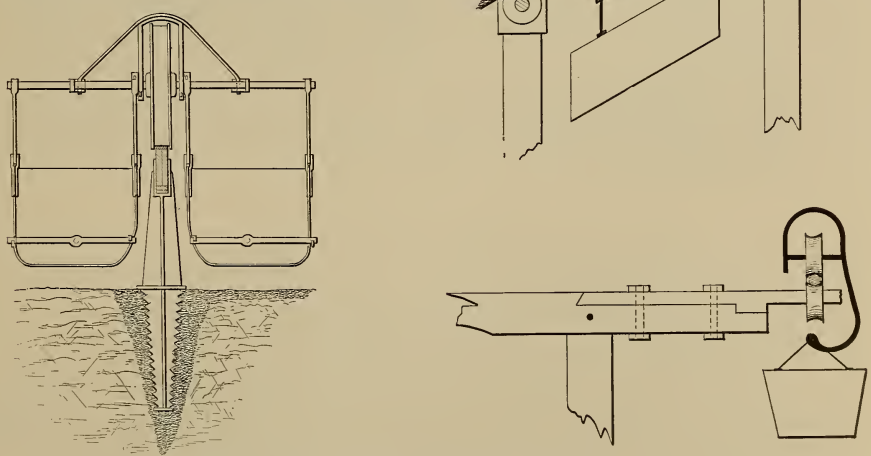


FIG. 3. THE SUSPENSION CABLE AND TOW-LINE ABOARD SHIP.

The use of the tow-line for raising and



FIGS. 4 AND 5. SUSPENSION CABLE RAILWAYS.

transporting bodies is illustrated by the three engravings, Figs. 6, 7 and 9, of models in the at one time famous museum of M. Grollier de Serviere at Lyons. The illustrations are taken from the descriptive work of his grandson, entitled "Recueils d'ouvrages curieux de mathematique et de mechanique, on description du cabinet de Monsieur Grollier de Serviere, avec des figures en taille douce, par Mr. Grollier de Serviere ancien Lieutenant-Colnel

d'Infanterie, son petit fils. A. Lyon, Chez. David Forey, Library ruë Merciere proche la mort qui trompe, MDCCXIX. Avec approbation et privilege du Roi." The senior Serviere died in October, 1689, aged 93, and, therefore, it seems probable that the cabinet or museum must have been formed as early as 1660, if not before.

Fig. 6 shows the use of the tow-line for raising a canal boat from one level to another. Save the employment of a truck platform to carry the boat, this is the same method that has been in use on the Grand Canal of China since its completion in the year 202 B. C. Robert Fulton, in 1796, published a work on canals, in which he advocates substantially the same system.

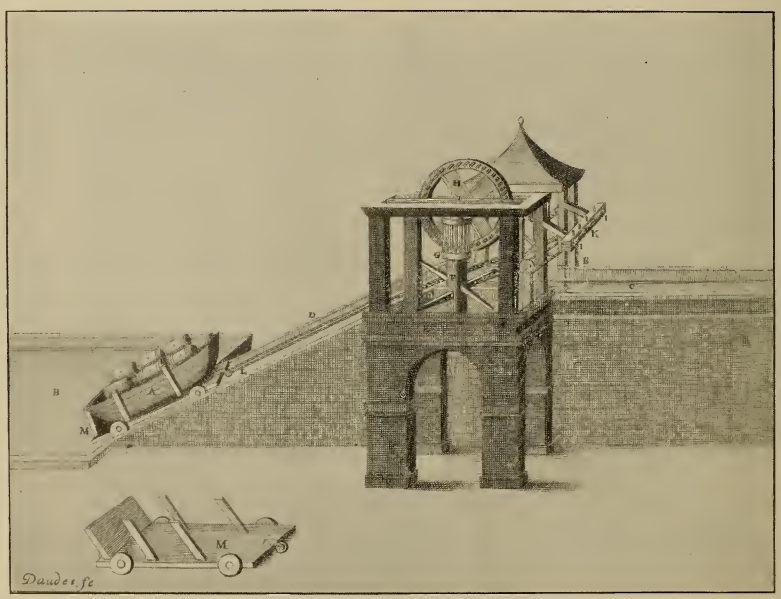



FIG. 6. RAISING A CANAL BOAT WITH A TOW-LINE.

Fig. 7 illustrates Serviere's method of compelling a stream to pull up a loaded barge against the current by the use of a tow-line attached to a descending boat. The water is supposed to be moving in the direction of the arrow. The boat on the right is at the head of the rapids, and is provided with a broad paddle, which may be raised or lowered by a winch. As soon as the tow-line is fastened to the boat at the foot of the rapids, this paddle is gently lowered; when it is sufficiently immersed, the pressure of the current on it will carry the right-hand boat down the rapids and the left-hand boat will therefore ascend against the current.

Fig. 9 represents an ingenious method of raising water to a kitchen window from a well at some distance from the house. An inclined suspension cable, A, is fastened to an anchorage, C, in the earth and to the end of a bracket, B, projecting from the wall of the house. This cable is placed in the same vertical plane as the axis of the well. Embracing the cable is a light frame of wood, containing two grooved pulleys, E and D, the latter running upon the cable and the former guiding the bucket tow-line F, which also passes over another guiding pulley, G, suspended from the bracket B. When the bucket commences to descend from the window, the wooden frame and its pulleys move with it, the grooved pulley, D, running down upon the suspending

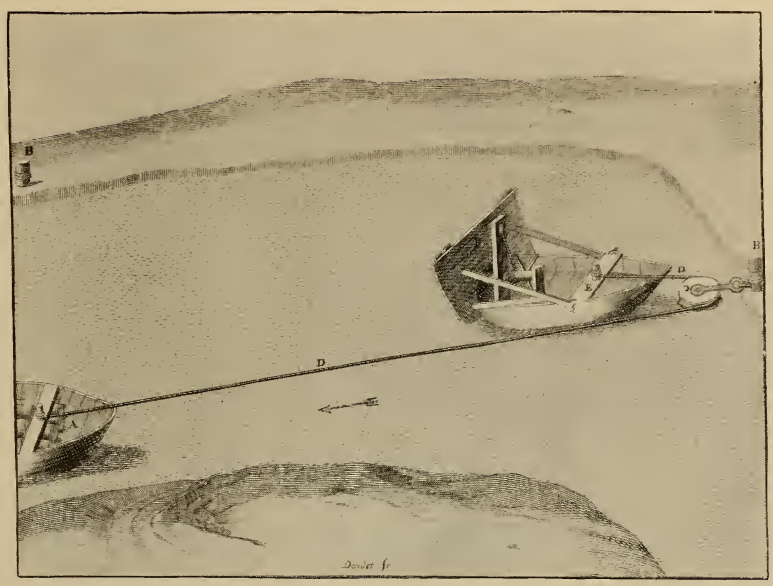



FIG. 7. PROPELLING A LOADED BOAT UP STREAM BY A BOAT GOING DOWN STREAM

cable, A, until it encounters the large knot, or protuberance, at A. The wooden frame can then descend no further, but as the bucket tow-line, F, continues to be payed out by the person manœuvring it, the bucket will descend into the well and, in due time, become filled with water. Then, by reversing the movement of its tow-line, the bucket is raised from the well, and when it reaches the wooden frame, that, with its pulleys, is carried up along the cable until the bucket comes within reach of the person at the window.

The first recorded proposal for a moving suspension cable carrying a suspended load at intervals and thus dispensing with a tow-line, or, rather, combining the functions of suspension cable and tow-line, is found in a work

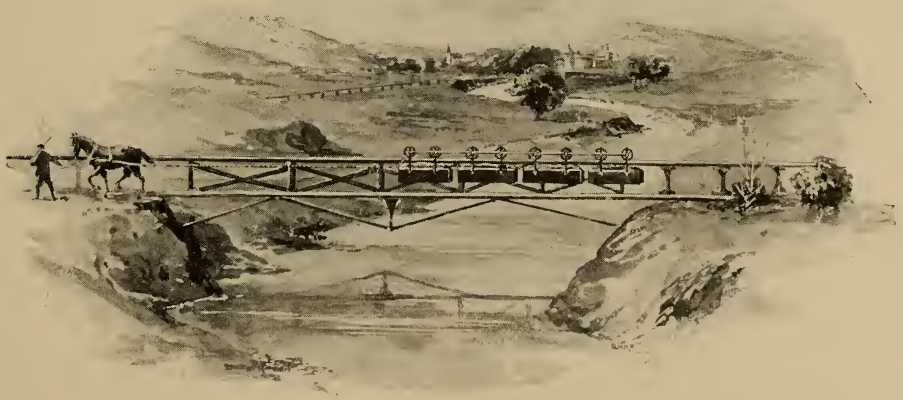


FIG. 8. PALMER'S SUSPENSION CABLE RAILWAY.

by "Venteri Mandey, Philomat." *

Fig. 10 represents "engin VI" of Mr. Mandey's work. This "engin" was designed "to remove a mountain or heap of earth from one place to another easily and quickly." The "engin" is quaintly described as follows: "Let the mountain, or hill, or heap of stones be A,† to be removed to a place B; to save time in going and returning from one place to the other, as also, that the motion whereby the earth or stones is transferred from A to B may be swift; we may make use of the following industry: Erect at the foot of the mountain, or in its middle, a great and solid wooden column, or piece of timber, C D, and erect such another in B, viz., E F. Affix at top of each piece or column the wheels D and F, and make hollow each wheel in the circumference and put about them a great strong rope, extended parallel to the horison. But if the distance from A to B be great, least the rope should be too much stretched or bent, raise other such like pieces or columns in the middle, with their wheels made hollow as aforesaid, to sustain the rope parallel to the horizon; on the rope thus doubled, here and there hang baskets which must be so far distant from each other that they hinder not one another, and the ends of the pieces must be so placed that the power applied to the levers G and H may be turned about their centres; for so the whole rope, with the baskets hanging on it, will be turned about successively. Wherefore, if men keep filling the baskets in A, and others unload them in B, the whole hill will be easily transferred from A to B. Where, note, that the greater the wheels D and F are, the swifter the rope and baskets will be turned about. Which motion about the axis, or piece of timber, being easie, may be accomplisht by means of short leavers, that so the motion of the baskets may be greater than the motion of the power about the piece of the timber. Besides the saving of labour and the gaining of time, which is effected by this engin, it hath likewise this conveniency, that if be-

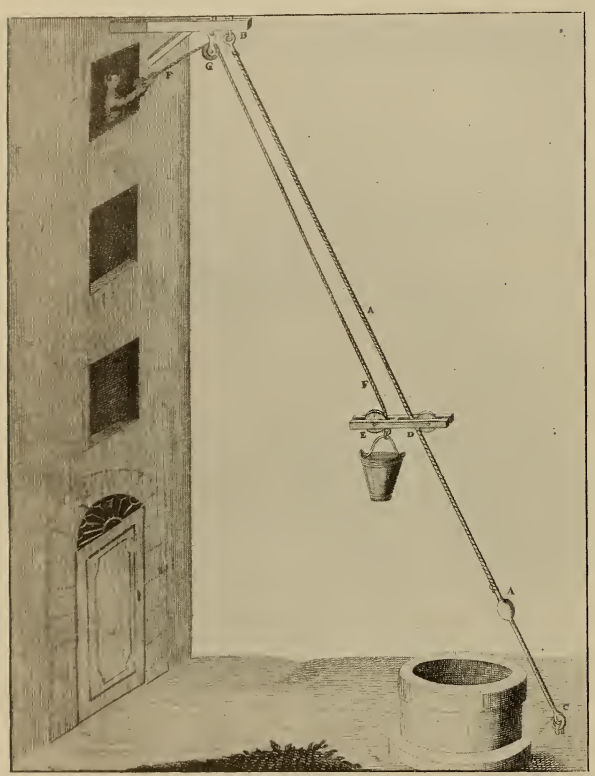


FIG. 9. OLD METHOD OF RAISING WATER FROM A WELL.

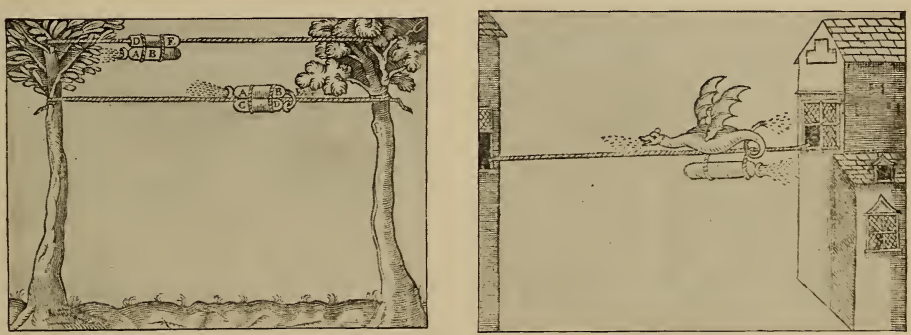
* Mechanick powers, or the mystery of nature and art unvail'd, shewing what great things may be perform'd by mechanick engines in removing and raising bodies of vast weights with little strength or force; and also the making of machines or engines for raising of water, draining of grounds and several other uses. Togeather with a treatise of circular motion artificially fitted to mechanick use, and the making of clock-work and other engines. A work pleasant and profitable for all sorts of men, from the highest to the lowest degree, and never treated of in English but once before, and that but briefly. The whole comprised in ten books, and illustrated with copper cuts. By Ven. Mandey, Philomat. London. Printed for Tho. Shelmerdine at the Rose tree, and Tho. Ballard at the Rising Sun in Little Brittain, 1702.

† The artist in deference to artistic effect has omitted the letters of reference, but the imagination of the reader will have no difficulty in supplying them.

tween the two pieces A and B there should be a river or stream, or such like inaccessible, as if the earth were to be transferred from a mound or hill to the next adjoining fields, and there were a large deep mote or ditch between them, you could scarcely obtain your desire any other way.''

FIG. 10. MANDEY'S CONVEYOR.

The first instance in which the load on a suspension cable carried its own motive power is believed to have been furnished by the ''swivel'' or ''flying dragon,'' so often seen in exhibitions of fireworks. This device is supposed to have had its origin in China, and is of unknown antiquity. One of the earliest English descriptions of it is contained in a work by John Bate, entitled ''The Mysteryes of Nature and Art,'' and published at London in 1634. From this Figs. 11 and 12 have been taken. Mr. Bate tells us that '' 'swevels' are nothing else but rockets, having instead of a rod (to ballast them) a little cane bound fast unto them, where through the rope passeth. Note that you must be carefull to have your line strong, even and smooth, and it must be rub'd over with soap that it may not burn. If you would have your rockets to returne againe, then binde two rockets togeather, with the breech of one toward the mouth of the other, and let the stouple that primeth the one enter the breech of the other. Both kinds are expressed by the figures, the uppermost whereof representeth the single one; A B signifieth the rocket D E, the cane bound unto it, through which a rope passeth. The lowermost representeth the double rocket; A B signifieth one rocket, and C D another; E the stouple that primeth the one and entereth the breech of the other.



FIGS. 11 AND 12. THE FLYING DRAGON.

''The flying dragon (Fig. 12) is somewhat troublesome to compose; it must be made eyther of dry and light wood or crooked-lane plates,* or of thin whalebones covered with Muscovie glass,†

* These were tin-plates, which were sold in a short London street called ''Crooked Lane.''

† This was isinglass, which at that time was found only in ''Muscovie,'' as Russia was then called.

and painted over. In the body thereof there must be a voyde cane to passe the rope through ; unto the bottome of this cane must bee bound one or two large rockets, according as the bignesse and weight of the dragon shall require. The body must be filled with divers petrars, that may consume it, and a sparkling receipt must be so disposed upon it that, being fired, it may burne both at the mouth and at the tayle thereof, then hang wings on in such wise that they may shake as the dragon runnes along the line ; you may dispose divers small serpents in the wings."

These old ideas of tow-line propulsion are the foundation of all funicular mechanisms,—rope transmissions, cable systems, conveyors, and telo-dynamic cables. Suspension bridges have been developed from a clothes line, and cable systems from a tow-line.

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# STORAGE BATTERIES FOR ELECTRIC TRACTION.

*By Pedro G. Salom.*

THE use of storage batteries for electric traction, and more particularly for operating street cars, has been so thoroughly discussed and so universally condemned by electrical engineers and practical business men engaged in the operation of street car lines, that it requires some courage, in the face of such a widespread belief, to urge that these gentlemen can all be mistaken, and yet a careful study of the problem, extending over a period of eight years, compels the author not only to dissent from their views, but to assert that in his opinion storage battery traction in the streets of our great cities will be well nigh universal. All the wires and poles must come down and the costly investment in underground feeders and mains be dispensed with. We are led to these conclusions by the following considerations :

Assuming, for the sake of argument, that electric storage traction is practicable, what are the problems that confront the engineer? The first and most important is the life of the battery. Then come the capacity, the rate of discharge, the weight and size of the elements, the loss of power in the various transmissions between the prime mover and the axle ; the distance or total length of line, the grade and curves, and the speed.

In traction work there is only one reliable method of determining the life of the battery, and that is on the basis of car mileage. It is nonsense to talk about batteries lasting eight months or eighteen months, unless there is a record, at the same time, of the amount of work accomplished, measured in electrical horse-power-hours. The highest record yet obtained, of which the writer has any reliable knowledge, is that of a single set of 108 accumulators making over 6000 miles. This record was made under the most trying and unfavorable circumstances. Assuming that the battery could make 100 miles per day, this would mean that the positive plates of the battery would have to be renewed every two months ; if fifty miles per day, then the life would cover a period of four months ; at twenty-five miles per day, eight months, and so on. It can thus be readily understood that the bare statement that a battery would last six or eight months does not convey a correct idea of the real life of the battery.

Let us see what it would cost to run 6000 miles with a single set of accumu-

lators, or, since two sets are always employed, one being charged while the other is in service, we will make a calculation on a basis of 12,000 miles.

| | |
|---|---|
| 216 Positive groups at $2.50..... | $540.00 |
| Credit 2592 pounds lead scrap at 3 cents ..... | 77.76 |
| Balance ..... ... | $462.24 |

$462.24 ÷ 12,000 = 3.85 cents per car mile.

If positive groups were renewed at $1.25 per group, instead of $2.50 each, which it would be perfectly possible to do, leaving out the question of patents and royalties, then the cost per car mile would only be 1.6 cents.

What amount of work is represented by these 6000 miles, so far as the accumulators are concerned? It was found by keeping the most careful records on the Fourth avenue line at New York, that the amount of energy consumed per car mile was about one and one-half electrical horse-power-hours. That is to say, that after making a round trip of eleven and one-half miles, it required about seventeen electrical horse-power-hours to replace the energy drawn from the batteries. Six thousand miles would, therefore, require 9000 electrical horse-power hours, and since a battery of 108 cells has a capacity of fifty-four electrical horse-power-hours for each total discharge, if we divide 9000 by 54 we get 166 total discharges that are required of the battery, before the positive plates break down. Any one who has had any extensive experience with storage batteries knows that this is a very conservative estimate of the amount of work that a good battery will perform.

It may be asked, have there been no improvements in late years with a view of diminishing the number and weight of batteries required to propel a car? We regret to have to answer no, and this brings us to the consideration of the limitations of storage batteries. We have said that it requires about one and one-half electrical horse-power-hours per car mile, and that 108 accumulators are used and necessary for a twelve-mile run, and they have a capacity of fifty-four electrical horse-power-hours, or three round trips.

Why is it not possible to use a battery with one-third the weight? Simply because the weight of battery required is not according to the total amount of work to be done, but according to the rate at which it is to be done. Let us go back to our twelve-mile run again. This requires one and one-half electrical horse-power-hours per car mile, or 1119 watt-hours, and since the electro motive force is about 225 volts, this would be equivalent to nearly five ampère-hours per mile, or sixty ampère-hours for the round trip; and since the trip consumes two hours' time, this is an average rate of discharge of thirty ampères all the time.

Of course, it is very much greater than this at times, when the car starts, or is going up steep grades, when the battery is frequently called upon for a rate of discharge of over 100 ampères. Now, if we were to use a small battery of less total capacity, there would not be sufficient area of active material exposed to develop such a current, the electro motive force would drop and the car stop running. This is the trouble with all thick plate batteries in traction work. The amount of surface area exposed is comparatively small for the weight of battery.

It seems to the writer, in view of the facts just stated, and which are indisputable, that the introduction of storage traction for surface roads in large cities is inevitable. The trolley may be introduced at the present time, pending the solution of the difficulties under which storage batteries have come into disrepute, but that it can obtain, in the long run, against the many and obvious advantages of the storage system is unlikely. Let the public once understand that there are no insurmountable difficulties connected with the storage system, beyond the fact that it costs a few cents more per car mile than the trolley, and the demand for its introduction will be irresistible.

The public are not interested in the cheapest and most objectionable method

of transit, especially where they derive no benefit from the economies effected, but they are interested in and entitled to a safe, reliable and absolutely unobjectionable method of transit, which is cheaper than horses at the present time, and which may, in a few years, from the further knowledge and experience gained by actual use, almost, if not quite, compete in cost with the trolley.

It is absolutely certain that all power houses for trolley lines will be compelled to introduce storage batteries for equalizing their loads. As at present operated, the power houses are called upon without a moment's notice to supply power varying from 50 to 500 horse-power. This can be accomplished only by employing large units, and the economic losses arising from operating large units at less than their maximum load are too well known to require comment. Storage batteries will gradually be introduced, first for running night cars, which will permit of the power plant being shut down after twelve o'clock, and, finally, on the day cars, as the efficiency of a large power plant operated with a constant load, day after day, charging batteries, and the saving in cost and maintenance of the line will more than counterbalance the cost of renewals of positive plates.

The most successful application of storage batteries for power purposes, up to the present time, is in electric launches. This method of navigation for inland waters was first demonstrated on a large scale at the World's Fair at Chicago last year, when fifty-four electric launches were in daily operation, and carried during the six months of the exhibition upward of one million passengers.

Another, and possibly more important, use than any yet attempted is the propulsion of all kinds of vehicles with storage batteries. Street cars number but a handful compared with all the carriages, wagons, carts and drays that are employed daily for the various purposes of local transportation. The successful introduction of electrically propelled vehicles is simply a question of good pavements and good roads. The cost of operating such vehicles would be far less than with horses.

For example, a battery of sixty accumulators of eighty ampere-hours capacity, capable of a maximum development of three horse-power, would cost at the present time $427.50, a three horse-power motor $200, making $627.50, or ten cents per day interest on the investment. The electrical capacity would be 9600 watt hours or about thirteen horse-power-hours. To propel a vehicle weighing about two tons on good, level roads, at ten miles per hour, would require about four horse-power. The battery would, therefore, have a capacity for at least three hours' work, or a thirty-mile run at maximum speed, and over fifty miles at normal or slow speed. Thirteen horse-power can readily be generated at the rate of two cents per horse-power per hour, or twenty-six cents. Assuming that the positive plates would last 200 days and make 6000 miles, or an average of thirty miles per day, the cost for renewals would be about seventy-five cents per day, making the total operating expenses $1 per day for thirty miles, or three and one-third cents per mile. Such a vehicle would do the work of several horses, but even if it replaced only two, it would be far cheaper in the long run than operating with horses.

# SUPERHEATED STEAM.

*By Professor W. Cawthorne Unwin, F. R. S.*

A FEW years ago an old beam engine, built by James Watt, which had been doing regular daily work for 102 years, was taken down and replaced by a modern engine. The engine was originally a 35 horse-power engine, and was erected in 1785. In 1795 some alterations were made to enable it to work to 70 horse-power. It had a 24-inch cylinder, a 6-foot stroke, and sun and planet motion. It worked at 22½ revolutions, or 270 feet of piston speed, per minute. In 1875 it was tested by Mr. M. Longridge, when, with a steam pressure of 5 pounds per square inch, it indicated 48.72 horse power, with an expenditure of coal of 4.59 pounds per indicated horse-power per hour. Only the best modern engines with the same condition of loading would work with 2 pounds of coal per indicated horse-power per hour. One is in doubt whether to be surprised that, after a century of endeavor to improve the economy of steam engine working, the progress is so small, or to be proud that so much has been achieved.

Early in the century it became clear that there were three directions of modification of the steam engine promising a gain in economy. Increasing the steam pressure was obviously desirable, primarily because the greater the boiler pressure used, the less the cost of an engine for a given power. But in non-condensing engines especially there was a gain in economy of fuel also, because the negative work of the return stroke became a less fraction of the absolute work of the steam. Increase of speed was desirable, but again chiefly for the commercial reason that the cost of the quick engine was less than that of the slow one. The importance of speed in diminishing steam consumption per indicated horse-power per hour has only slowly been realized. A third direction of improvement, the increase of the ratio of expansion, promised to be the most important of all in increasing the economy of the engine. Unfortunately, practical experience did not confirm the promise.

Except in one peculiar case, which was long an anomaly in engineering practice, it was found to be most economical to use moderate ratios of expansion. In the case of the Cornish pumping engine, it is true, high ratios of expansion were used apparently with economical advantage. But the cause of the greater economy of expansive working in Cornish single-acting engines, namely, that the admission surface in the cylinder is never exposed directly to radiation to the condenser, has only quite lately come to be understood. The peculiar advantage of great expansion in this case was long attributed to the convenient adjustment between the diminishing pressure on the piston and the decreasing effort required for the lifting of a heavy mass of pump rods, which had to be put in motion at the beginning, and brought to rest at the end, of the steam stroke. In factory and marine engines the advantage of working at high ratios of expansion was for a long time limited or annulled by some unknown action, and engineers like Siemens and Ericsson were driven to abandon steam as the working fluid in the engine, in the hope of realizing a higher economy by using a permanent gas.

The considerable advance in the economy of steam engine working in the last forty years has partly arisen accidentally from the circumstance that there were purely commercial advantages in building engines to work at

higher pressures and faster speeds. But it is also largely due to the growth of more accurate knowledge of the behavior of steam in the engine and of the conditions on which economical working depends. The greatest step in the advancement of our knowledge of the action of steam in the engine is due to experimental researches carried out in Alsace. Those researches showed immediately that the action of steam in the engine cylinder, apparently very simple, is really very complex, and is attended by condensations and re-evaporations large in amount relatively to the quantity of steam used.

Some early writers, Combes in 1845, and Richard in 1851, perceived that the cylinder wall—cooled during expansion and exhaust and heated again during admission—must exert a prejudicial action on the economy of the engine, and they reasoned about this action with singular force and accuracy. But it was in the classical researches of Hirn at Logelbach in Alsace, in 1855, that the fact of initial condensation was first demonstrated and its amount measured. The magnitude of the condensing action is surprising. Here are the figures for some of Hirn's trials of a simple engine using saturated steam :

| | | |
|---|---|---|
| Ratio of expansion..... | 4 | 7 |
| Weight of steam used per stroke in pounds..... | 0.814 | 0.574 |
| Percentage of water entrained in the boiler, steam..... | 1.0 | 0.8 |
| Percentage of water present in the steam at cut-off. . | 31 | 37 |
| Percentage of water present in the steam at release..... | 25.2 | 35.2 |

In these results there was the demonstration of a prejudicial action in the cylinder, increasing with the ratio of expansion, and the key to the understanding of the failure to realize the economy expected from expansive working. It became clear that the pure thermo-dynamic theory of the steam engine, then taking shape in the hands of Rankine and Clausius (a theory mathematically exact with the restrictions assumed, but which ignored the influence of the conducting cylinder) required very large corrections of a kind which could be determined only by experiment. To experiment, Hirn and his coadjutors, Leloutre, Hallauer, Dwelshauvers - Dery, with Walther Meunier and the members of the Alsatian Society of Steam Users, addressed themselves, and an exceedingly valuable mass of experimental data was accumulated between 1855 and 1875. The careful analysis of the results, on Hirn's method of analysis, made intelligible, for the first time, the influence of jackets and compounding on the economy of the steam engine. Just at the same time the experiments of Isherwood very usefully confirmed the Alsatian researches. The most important modifications of the steam engine since 1855 which have any relation to economy of working may all be described as methods of reducing, absolutely or relatively to the work done, the prejudicial action of the cylinder wall.

The heat exchange with the cylinder wall is a phenomenon not at all obscure in itself, but the conditions in which it occurs are complicated. The interior of the cylinder to which the steam is exposed changes every moment in area ; there are parts which are black and parts which are bright, surfaces from which water drains and surfaces on which water lies, parts receiving heat from a jacket and parts losing heat by radiation, and the water or dew covering some parts of the wall modifies the action of the metal. The amount of heat exchange cannot be reduced to simple rules of thumb for the guidance of practical men. Nay, more, to understand the relative magnitude, in different cases, of the action of the steam and wall, involves patient study of the experimental evidence and familiarity with thermo-dynamic calculation. Although a few engineers, like the late Mr. Willans, realized the fundamental importance of studying the cylinder condensation as an instrument for discovering the conditions of the economical use of steam, and a guide in the practical design of engines, many practical engineers have remained ignorant of the whole matter. *De non existentibus et non apparentibus eadem est ratio.*

Those things which it would be troublesome to understand, it is most convenient to treat as non-existent.

The whole subject of thermo-dynamic labors to some extent under the same difficulty. Thermo-dynamic reasoning is just difficult enough to require more patience and steadiness of thinking than ordinary people are prepared for. Put aside mere paradoxers who are in difficulty about Joule's equivalent and the absolute zero of temperature, and Carnot's law, and who unload their ignorance in the correspondence columns of technical journals at inordinate length. Even in serious attempts to discuss the steam engine, and in the conversation of practical engineers, one too frequently comes on errors and misunderstandings which an elementary knowledge of thermo-dynamics would render impossible.

In an appreciative memoir of the late President of the French Republic, in the latest volume of the proceedings of the Institute of Civil Engineers, there is a reference to the classical pamphlet on heat engines of his distinguished relative Sadi Carnot. It is stated that Sadi Carnot "demonstrated that whenever work is produced there is a transmission of heat, and enunciated the law which is recognized as the basis of all true formulas devised for the measurement of the efficiency of thermo-dynamic machines." It would be difficult to compress a greater amount of confusion into as many words. If work is done in a heat engine, heat is not transmitted, it is transformed. But this was not demonstrated by Carnot, but by Rumford, and Mayer, and Joule. Carnot did not even know of the convertibility of heat and work, but accepted, with some hesitation it is true, the idea of his time that heat was a material substance. What he did demonstrate was, that when work is done in a heat engine, some material body falls in temperature. Carnot's law, modified to eliminate the error due to his wrong conception of the nature of heat, is not the basis of all true formulas of heat engine efficiency; it is a statement of the efficiency of all reversible heat engines, which is a quite different matter. Now, if there is such confusion, so loose a grasp of elementary principles, in a technical memoir of an engineer, what may be expected of ordinary practical manufacturers and users of steam machinery? If one of the fundamental laws of thermo-dynamics is so misapprehended, what of the much more complex and recondite actions which make up the action of steam in a cylinder?

The digression is necessary to explain how it has come about that while, in 1855, it was shown that by far the largest cause of waste in the use of steam was the, to a great extent preventible, condensation in the cylinder, engineers have addressed themselves so slowly and fitfully to that principal defect. Endless ingenuity has been expended on modifications of valve gear which, at best, could have very small effect, while a far more profitable field of improvement was in open view. But the steam jacket was neglected or its advantage questioned by engineers who, at the same time, were attributing an enormously exaggerated importance to a sharp cut-off or a particular amount of compression.

Recently, in an American engineering journal, a correspondent, after a sneer at "Hirn & Co." and their "laboratory experiments," gave a geometrical proof of the waste of heat due to throttling instead of automatically varying the cut-off. This correspondent is quite ignorant that the whole question turns upon exactly those considerations of condensation in the cylinder which this mode of treatment ignores. It ought not to be necessary, forty years after Hirn's work, to point out that the steam shown by a diagram is not the quantity of steam used by the engine.

When some engineers are faced by the fact that there is large condensation in engine cylinders, they allege that it is due to boiler priming, or to what they term condensation due to the work done. In no ordinary case would these causes explain one-fourth of the

condensation actually found,—in many cases not one-tenth. The condensation in question is of quite another kind, and is entirely due to the conductivity of the cylinder wall. It is not necessary in this paper to distinguish between the action of the metal and that of the moisture which, generally, in part covers it.

Granting the fact of a large initial condensation of the steam in an engine cylinder, due to the antecedent cooling of the wall during expansion and exhaust in the previous stroke, the question is in what way it can be diminished. There are four known means of diminishing the prejudicial condensing action of the cylinder wall,—the steam jacket, superheating, multiple stage expansion, and high rotational speed. But as each of these means attacks the same source of loss, and borrows an economy by arresting the same waste, it is not to be expected that they can be used in combination without, to some extent, neutralizing each other's action. At the same time, by no one of these methods has the whole condensing action in the cylinder been hitherto prevented. Two questions are, therefore, open in any given case—which of these methods is the most convenient and least costly to use? And next—one of these methods being adopted, will it still pay to adopt supplementarily a second also?

It is to one of these methods which seems to have been hitherto too much neglected that the author wishes to draw attention in this paper. Superheating the steam not only attacks cylinder condensation in the most direct and effective way, but it seems to be specially suitable to be adopted as a supplement to one of the other methods of economizing steam.

In 1855–6, Hirn published the results of the first complete engine experiments in which the amounts of heat expended in doing work, and in various ways wasted, were separately determined. He was led at once to perceive the importance of the condensations and re-evaporations which go on within the cylinder. He attributed these to the action of the conducting cylinder wall, and consequently he proceeded at once to examine the action of the steam jacket, and the extent to which it diminished the cylinder condensation. Then a more effective way of conveying a supply of heat to the cylinder wall presented itself. By superheating the steam before admission, it was provided with the means of heating the cylinder wall without condensing. In 1855 and 1856, Hirn carried out comparative trials, both with a simple and a Woolf engine, with ordinary and superheated steam. From the first, Hirn satisfied himself that the marked economy in the trials with superheated steam was due entirely to the exchange of heat with the cylinder wall during admission, for he found that even with steam superheated to 460 degrees Fahrenheit the superheat was lost, and an appreciable part of the steam condensed before cut-off.

The following short table shows some of the results obtained in a repetition of these trials in 1873–5. They show clearly the gain due to superheating, and the reduction of the amount of water present in the cylinder.

| | Ordinary Steam. | Superheated Steam. | Ordinary Steam. | Superheated Steam. |
|---|---|---|---|---|
| Real ratio of expansion | 6.2 | 6.2 | 3.9 | 3.9 |
| Boiler pressure, lbs. per sq. in | 56.0 | 55.9 | 51.4 | 54.9 |
| Temperature of superheated steam | .... | 384° | .... | 448° |
| Amount of superheating | .... | 81° | .... | 146° |
| Indicated H. P | 107 | 113 | 136 | 144 |
| Steam per I. H. P. hour, lbs | 19.4 | 16.2 | 21.5 | 17.4 |
| Economy due to superheating, per cent | .... | 20 | .... | 22 |
| Per cent. of steam condensed at cut-off | 37.0 | 24.6 | 31.0 | 6.5 |
| Per cent. of steam condensed at release | 35.2 | 21.4 | 25.2 | 12.0 |

Professor Cotterill has shown that in any heat process there is a "pressure equivalent to the heat expended" in

such a sense that, if a diagram is drawn with the volume described by the piston as abscissa and the equivalent pressure as ordinate, the heat expended is given by the area as in an ordinary indicator diagram. Professor Dwelshauvers-Dery has used this method to represent the heat exchange with the cylinder wall during a complete stroke. Fig. 1 shows two such diagrams superposed for the two trials given above. Each diagram consists of two areas, one the heat given to the wall during compression and admission ; the other, the heat abstracted during expansion and release. Necessarily in each diagram, for steady running, these areas are equal. The figure shows how much the heat exchange with the wall is diminished by superheating.

Soon after the demonstration by Hirn of the fact of an important initial condensation in steam engines, and the proof that this could be reduced and an important economy realized by the use of superheated steam, many patents were taken out for different forms of superheaters, and many engineers applied superheating apparatus to marine and land engines. Much information as to what was done at that time may be found in three papers by John Penn (Proc. Inst. Mech. Eng., 1859), by the Hon. John Wethered (Proc. Inst. Civil Eng., 1860), and by John N. Ryder (Proc. Inst. Mech. Eng., 1860). It was due to the influence of John Penn, especially, that the practice of superheating steam was very largely adopted, for a time, by marine engineers. He states that Mr. Howard and Dr. Haycraft first advocated superheating, and that they were convinced that an economy of 30 per cent. would be realized. But he does not indicate on what grounds they thought that superheating would be advantageous, nor does he say that they had proved it by any direct experiment.

Penn himself seems to have been induced to experiment on superheating by the arguments of Dr. Haycraft, and after trying it on a large scale he came to the conclusion that with steam superheated 100°, an economy of from 20 to 30 per cent. of fuel was obtained, and that its use involved no extra wear and tear, no serious complication and no difficulty of lubrication. Further, bearing in mind the fact that Penn was a practical engineer, it is noteworthy that he describes quite accurately the cooling of the cylinder wall during exhaust, and the consequent condensation of fresh steam in the cylinder during admission, and attributes the benefit of superheating to the prevention (putting it rather too strongly) of this initial condensation.

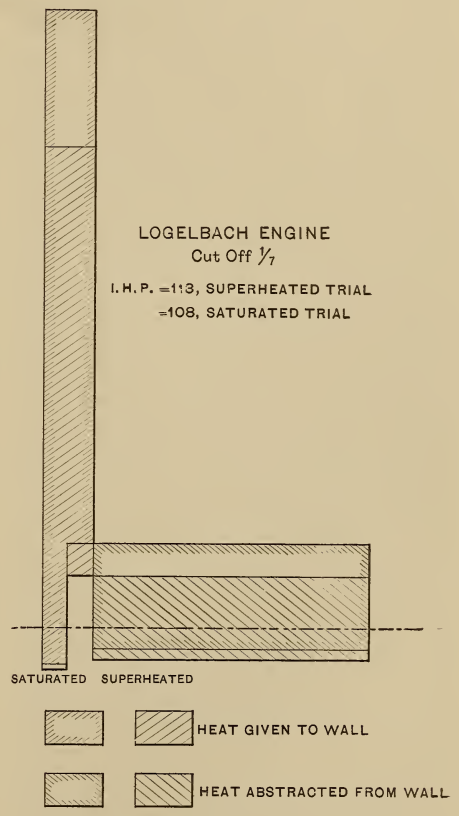


FIG. 1.

So important did Penn think this condensing action of the cylinder wall, due to radiation to the condenser (using the term radiation in a wide sense), that he says graphically, but quite accurately, "the steam engine must, in fact, be looked upon as only in degree better than Newcomen's atmospheric engine,

in which the whole of the steam was condensed in the cylinder at each stroke; and the advantages of Watt's great invention of condensation in a separate vessel are not fully realized until this serious defect is removed." Then he adds, "Now if as much heat be added to the steam by superheating it before entering the cylinder as will supply the amount of which it is robbed by the cylinder, it will remain perfect dry steam throughout the stroke, and not a drop of water will be deposited." This he believed to be the mode in which the superheating of steam "acts in producing a saving of steam and consequent saving of fuel, by preventing the extensive waste of steam that ordinarily takes place; and this indicates the extent to which superheating can be carried with any great advantage."

Penn was not aware that a certain amount of condensation, generally insignificant compared with the initial condensation, occurs during expansion, and he probably overstated the case in assuming that with any practically convenient amount of superheating all initial condensation could be prevented. Hirn had, in fact, already shown that superheating to a practical amount reduced, but did not entirely prevent, initial condensation. But these are minor inaccuracies. Apart from them, the whole rationale of the use of superheating could not be better stated, and Penn was in advance in clearness and accuracy of any of the engineers who took part in the discussion of the papers cited above.

It is clear from the three papers of 1859–60 that there was a unanimous agreement among all engineers who had tried superheating, that it secured an economy of steam and of fuel of from 20 to 40 per cent. John Penn stated that in his trials an economy of from 20 to 30 per cent. was realized, the steam being at 20 pounds per square inch pressure, and superheated 100° Fahrenheit, that is, to 360° Fahrenheit. Mr. Ryder had found an economy of 30 per cent. by using superheated steam for an engine at Woolwich Arsenal. He had also supplied superheating apparatus in the Osprey and the Swift, steamboats on the Thames, and obtained an economy of from 30 to 40 per cent. A trial of superheating apparatus on H. M. Steam Tug Bustler, gave an economy of 25 per cent. Mr. Hobbs stated that the addition of a superheating pipe in the flues of a Cornish boiler supplying a small engine, reduced the coal consumption from 36 to 28 cwts. per week. With increased superheating surface the consumption was 24 cwts. per week. Mr. Humphreys stated that he had introduced superheating apparatus in the vessels of the Peninsula and Oriental Company. In the Ceylon the consumption of fuel with ordinary steam was 1500 tons per voyage. Superheating apparatus was applied having one square foot of surface per indicated horse-power, and the fuel consumption was reduced to 1100 tons per voyage. In the Alhambra, with ordinary steam, the fuel consumption was 19 cwts. per hour; with superheated steam, 13 cwt. per hour. In the Nepaul, with ordinary steam, the fuel consumption was 36 tons per day; with superheated steam, 17 tons per day. Mr. Topham stated that he had applied superheating apparatus in one of the vessels of the International Royal Mail Company. With ordinary steam the fuel consumption was 2986 pounds per hour; with steam superheated to about 330°, the consumption was 1900 pounds per hour. Mr. Beardmore stated that in a steamer belonging to the General Steam Navigation Company the fuel consumption, with ordinary steam, was 126 tons per voyage; with superheated steam, 90 tons per voyage. The testimony to the saving effected by using superheated steam was unanimous, and the amount of saving observed was so large that it could not possibly be attributed to observational errors.

It is striking how well most of the engineers who took part in the discussions of 1859–60 understood the action in the cylinder and the cause of the economy of superheating. A few erroneous opinions were expressed. Mr. Cowper thought that with a jacketed cylinder there could be no condensation

in the cylinder. Mr. Robinson thought that the economy of superheating was due to the superheater taking up some of the waste heat of the furnace gases, and that it was virtually merely additional boiler surface. But Sir F. Bramwell immediately pointed out that this would not explain the reduced steam consumption in the engine when the steam was superheated. Generally, the practical engineers who had used superheated steam reasoned quite correctly. There is no trace in the discussions of the erroneous view put forward at a later date that the economy of superheating is due to the increased temperature range at which the engine works. An economy due to that cause might possibly arise with an excessive amount of superheating, but it would be small, and cannot be obtained when the steam cools to saturation temperature before cut-off.

Another point of importance to be gathered from the experience of 1859–60 is that whenever superheating was pushed to temperatures above about 360° or 400° Fahrenheit, some difficulty was found in preventing injury to the cylinder from the destruction of the lubricant. It probably became a fixed conclusion of practical engineers that steam must not be superheated above about 360°, and this was probably one reason why superheating came to be generally abandoned when the pressures at which engines worked were increased. At that time, however, cylinders were lubricated with tallow or animal oil, which decomposes at a comparatively low temperature. Now that we have mineral oils, which stand much higher temperatures before decomposing, we may naturally expect that the temperature at which danger to the cylinder begins will be higher.

Yet another point about the early superheaters must be noticed. Most of them, probably with the idea of utilizing some waste heat, were placed in the uptake where the products of combustion left the boiler; that is, they were placed where the temperature of the furnace gases was coolest and where the fluctuations of temperature were greatest. The coolness of the furnace gases after discharge from the boiler flues made it necessary, in most cases, to use very large superheaters with large surfaces. The great fluctuation of temperature involved as a result that the superheater was sometimes overheated and then became dangerous. Hirn's own superheater, which is still in existence at Logelbach, had enormously large area. Only one engineer, Mr. Pilgrim, was bold enough to use a small superheater placed near the furnace where the gases were hot. A feed heater is rightly placed in the uptake or discharge flue, for there is a sufficient difference of temperature between the temperature of the gases and the temperature of the feed to ensure tolerably rapid heat transmission. In the case of a superheater, with a smaller temperature difference between the gases and the steam, the heat transmission is slower and the heating surface much less effective.

Between 1860 and 1870 superheated steam was very extensively adopted, especially for marine engines. After 1870 its use was soon discontinued. The reasons for this were probably these :—(1) As the steam pressures used were increased, the range of superheating possible within the limit of danger to the lubricant was decreased, and the advantage of superheating correspondingly diminished. (2) The large superheaters in the uptake proved, in some cases, to be dangerous and liable to become overheated. (3) As the designing of steam machinery became more a matter of routine, and competition reduced the profits of engine building, the construction of engines fell into the hands of engineers who understood the action of the steam less well than the engineers who introduced superheating in 1859–60, and who regarded superheaters as unnecessary complications which it was convenient to abandon.

Probably it has come to be accepted as an axiom by most practical steam engineers that, in modern conditions of working, superheating is useless or impossible. Some reasons for such a be-

lief, arising out of difficulties experienced, no doubt there are. But if engineers generally had fully appreciated the magnitude of the loss due to condensation in the cylinder, it is difficult to think that superheating would have been abandoned with so little of a struggle to overcome the difficulties, and that, for so long, while every other means of securing economy has been tried, superheating has been neglected. It is sometimes said that the quantity of heat in superheated steam in excess of that in saturated steam is very small. That is so, of course. But the earlier experience showed that this small quantity produced a disproportionately large beneficial effect,

Two or three years ago the author became aware that superheaters were again being somewhat extensively introduced in Alsace, and that very considerable saving was effected with modern steam machinery working at comparatively high pressures, when steam was superheated. The superheaters mostly used were constructed under patents taken out by M. Emile Schwoerer and by M. Uhler. There are some details of construction in these superheaters which are important, but broadly they do not differ at all from the older superheaters except in this, that they are placed in a hot part of the boiler flues and not in the uptake or discharge flue. They can, therefore, be made comparatively small, and so strong that they are not dangerous, even if somewhat overheated. In some cases they are constructed with a separate furnace, and even these detached superheaters, in which the whole of the superheating is effected by the combustion of an extra quantity of fuel, are found to secure a resultant economy of coal.

The Alsatian Association of Steam Users, in whose journal Hirn's papers on the "Steam Jacket" and on "Superheating" originally appeared, still carries out, for the information of its members, careful tests of steam machinery. Various tests have been made by the very experienced and competent engineer of the Association, M. Walther Meunier, which show that with modern engines and boilers, working at modern pressures, superheated steam can be used without practical difficulties, and in such a way as to realize generally an economy of from 15 to 20 per cent. of fuel and of steam. Now there are in Alsace hundreds of steam boilers to which superheaters have been added, and of engines using, regularly, steam at a temperature of 450 degrees Fahrenheit, and sometimes of 500 degrees Fahrenheit.

The following tables contain the results of some trials with and without superheating. In these cases Schwoerer superheaters in the boiler flues were used. The smaller decimals have been struck out so that the general bearing of the results may be clearer. Gross coal includes coal used in starting the boiler.

*Case 1. Cotton Mill at Horbourg.*—Four boilers with economizer. In the trial with superheated steam two boilers were used with 984 square feet of heating surface, and 47 square feet of grate. For the trial without superheating, three boilers with 1486 square feet of heating surface, and 70 square feet of grate. The coal was Belgian coal. The engine was a Woolf engine.

| | With Superheated Steam. | With Saturated Steam. |
|---|---|---|
| Duration of trial, hours..... | 11 | 11 |
| Mean indicated H. P..... | 276 | 278 |
| Steam per I.H.P. hours, lbs. | 17.1 | 19.7 |
| Coal " " (gross) " | 2.4 | 3.2 |
| " " " (net) " | 2.0 | 2.7 |
| Temperature of superheating..... | .... | 432° F. |

*Case 2. Jute Factory at Bischwiller.*—Four boilers with economizer. For the trial with superheating three boilers were sufficient, with 1517 square feet of heating surface, and 75 square feet of grate. For the trial without superheating, four boilers were necessary with 2023 square feet of heating surface, and 103 square feet of grate. The economizer had an area of 2750 square feet. Griesborn coal. One compound and one Corliss engine working on the same shaft.

| | Superheated Steam. | Saturated Steam. |
|---|---|---|
| Duration of trial, hours..... | 10 | 10 |
| Mean indicated H. P..... | 564 | 554 |
| Steam per I.H.P. hour, lbs. | 17.4 | 21.8 |
| Coal " " (gross) " | 3.0 | 3.8 |
| " " " (net) " | 2.6 | 3 2 |
| Temperature of superheating..... | .... | 432° F. |

*Case 3. M. Koechlin's Factory at Massevaux.*—Three boilers and economizer. When working without superheating, a fourth boiler had to be used. Ronchamp coal. Engine, a new Corliss.

| | Superheated Steam. | Saturated Steam. |
|---|---|---|
| Duration of trial, hours..... | 11 | 11 |
| Mean indicated H. P..... | 309 | 310 |
| Steam per I.H.P. hour, lbs. | 15.7 | 19.0 |
| Coal " " (gross) " | 2.4 | 3.0 |
| " " " (net) " | 2.0 | 2.5 |
| Temperature of superheating..... | .... | 431° F. |

*Case 4. Silk Factory at Colmar.*—One boiler. A pair of horizontal engines with steam jackets. Hasard coal.

| | Superheated Steam. | Saturated Steam. |
|---|---|---|
| Duration of trial, hours..... | 11 | 11 |
| Mean indicated H. P..... | 119 | 116 |
| Steam per I.H.P. hour, lbs.. | 19 1 | 21.5 |
| Coal " " (gross) " | 2.6 | 3.5 |
| " " " (net) " | 2.4 | 3.1 |
| Temperature of superheating..... | .... | 477° F. |

These cases show that under the conditions in which steam engines work in the factories in Alsace, there is a very great advantage in using superheated steam. No doubt the conditions are somewhat favorable, for the engines are of types in which the cylinder condensation may be expected to be not inconsiderable. But these conditions are not unusual. Short stroke, high speed engines are not yet the most common type of engines, and though in them the condensation is diminished so that the loss out of which a saving can be effected is smaller, it is not at all clear that even with them the advantage of superheating would be so small that it would not be worth the cost. No doubt with such engines, jackets are comparatively ineffective, for both the surface through which the heat passes from the jacket to the cylinder steam, and the time for its transmission, are less than in slower engines. But the superheated steam carries heat into the cylinder, and yields it directly to the inner surface of the wall, and the quantity of heat so carried in is proportional to the quantity of steam used, and therefore increases along with the piston speed.

A year ago the author had an opportunity of examining the system of superheating now in use in Alsace, and of carrying out comparative trials with a large modern engine. The engine was a compound receiver engine with jacketed cylinders, working to about 500 indicated horse-power. It was supplied with steam by five elephant boilers of the type usual in Alsace, the working steam pressure being from 85 to 100 pounds per square inch. The boilers were supplemented by an economizer, or feed heater, and had very satisfactory automatic feed regulators. Each boiler had a heating surface of 629 square feet, and a grate surface of 29.2 square feet. Below the grates were chambers containing Schwoerer superheaters, through which the furnace gases could be taken immediately after passing the bridge.

Three trials were made, two with the superheaters in action and one with the superheaters stopped off. In the former case three boilers were used. In the latter it was found necessary, soon after beginning the trial, to use a fourth boiler, which had been got ready beforehand. The coal used was of poor quality.

The engine was a very excellent one, with four separate side valves to each cylinder. The governor was blocked and the engine run on an almost constant load. There was a somewhat long steam pipe from the boilers to the engine, and hence part of the temperature of superheating, about 60°, was lost between the superheaters and the engine. In the third trial the superheaters which had been put out of action on the previous day, did not work with full efficiency during the first hour. That trial has, therefore, been reduced in two

ways, first, taking the whole six hours' run, and next, taking the last five hours. The results are not very different, but are a little better for the last five hours. In all the trials the steam used by a donkey feed pump is reckoned as steam used by the engine. The engine had been using superheated steam for two years, and was in no way specially prepared for the trial. In fact, it was only selected for trial a day before the trials began, and during the trials it was driving the mill as usual.

It is obvious that the economy due to superheating is a considerable one. In Fig. 2 are given the indicator diagrams for one pair of trials with and without superheating. On the diagrams the saturation curves have been drawn for the weight of steam used per stroke. It is then easy to find the dryness fraction of the steam during the expansion in each cylinder. The following are the results :—

| | Saturated Steam. | Superheated Steam. |
|---|---|---|
| *High-Pressure Cylinder.* | | |
| Dryness fraction of steam at cut-off | 0.65 | 0.85 |
| Dryness fraction of steam at release | 0.76 | 0 96 |
| *Low-Pressure Cylinder.* | | |
| Dryness fraction of steam at cut-off | 0.65 | 0.84 |
| Dryness fraction of steam at release | 0.77 | 0.91 |

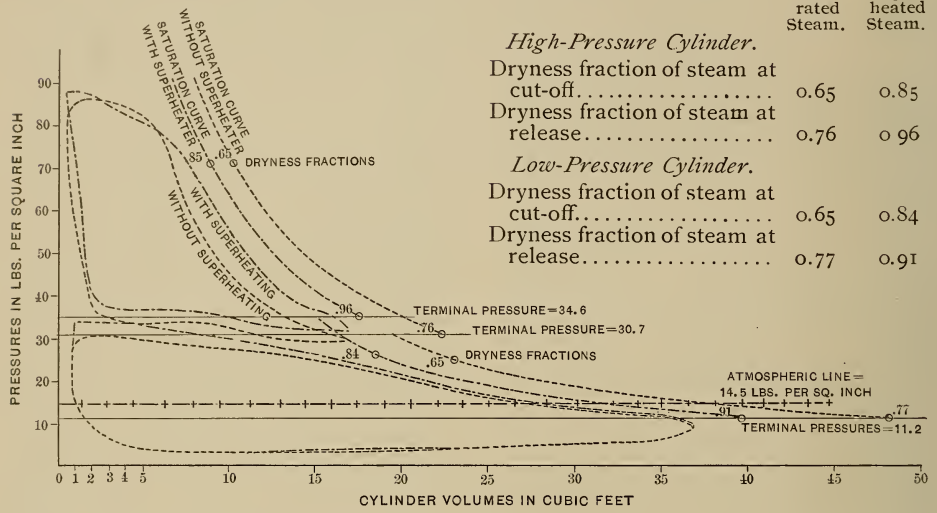


FIG. 2.

The greater dryness of the steam in the superheating trial is obvious. The economy due to the superheating is traceable to the diminution of the initial condensation and to the greater re-evaporation during expansion.

One final word is necessary. It must not be supposed that there are now no practical difficulties in using steam superheated to from 450° to 500°. But it does appear that with suitable arrangements and with experience those diffi-

TRIAL OF COMPOUND ENGINE AT LOGELBACH.

| | Saturated Steam. | Superheated Steam. | | |
|---|---|---|---|---|
| Duration, hours | 6 | 5 | 6 | 5 |
| Boiler pressure, lbs. per sq. in | 95.72 | 95.05 | 93.74 | 94.0 |
| Total indicated H. P | 475.0 | 491.0 | 501.4 | 502.3 |
| Temperature of steam at valve chest | 334.7 | 455.4 | 452.5 | 460.4 |
| Amount of superheating | None. | 118.3 | 119.2 | 126.9 |
| Revolutions per minute | 55.3 | 55.6 | 55.5 | 55.5 |
| Piston speed, ft. per min | 471.4 | 474.2 | 473.5 | 473.3 |
| Pounds of water evap. per lb. coal | 6.276 | 6.024 | 6.655 | 6.21 |
| Pounds of steam per I. H. P. hour | 19.75 | 15.63 | 17.06 | 15.61 |
| Pounds of coal per I. H. P. hour | 3.15 | 2.59 | 2.56 | 2.51 |
| Per cent. of steam condensed in jackets | 3.54 | 2.94 | 3.15 | 1.47 |
| Economy of steam, per cent., due to superheating | ..... | 20.9 | 13.6 | 20.9 |
| Economy of coal, per cent., due to superheating | ..... | 17.6 | 18.5 | 20.1 |

culties have been overcome. The object of this paper is rather to recall attention to the fact that one way of attacking the principal avoidable waste in steam working has been for many years neglected. Even if all that can be saved by superheating can also be saved by jacketing and compounding, it is still a question which method is the most convenient and the least costly. Superheating, providing it is practicable, is at any rate the most direct way of attacking the cause of exhaust waste.

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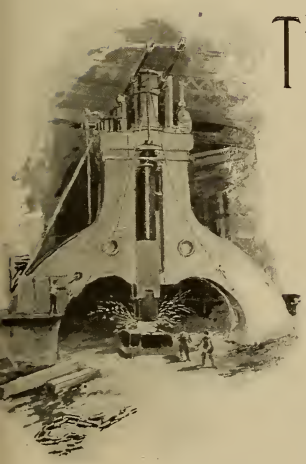
# HYDRAULIC MACHINE TOOLS.

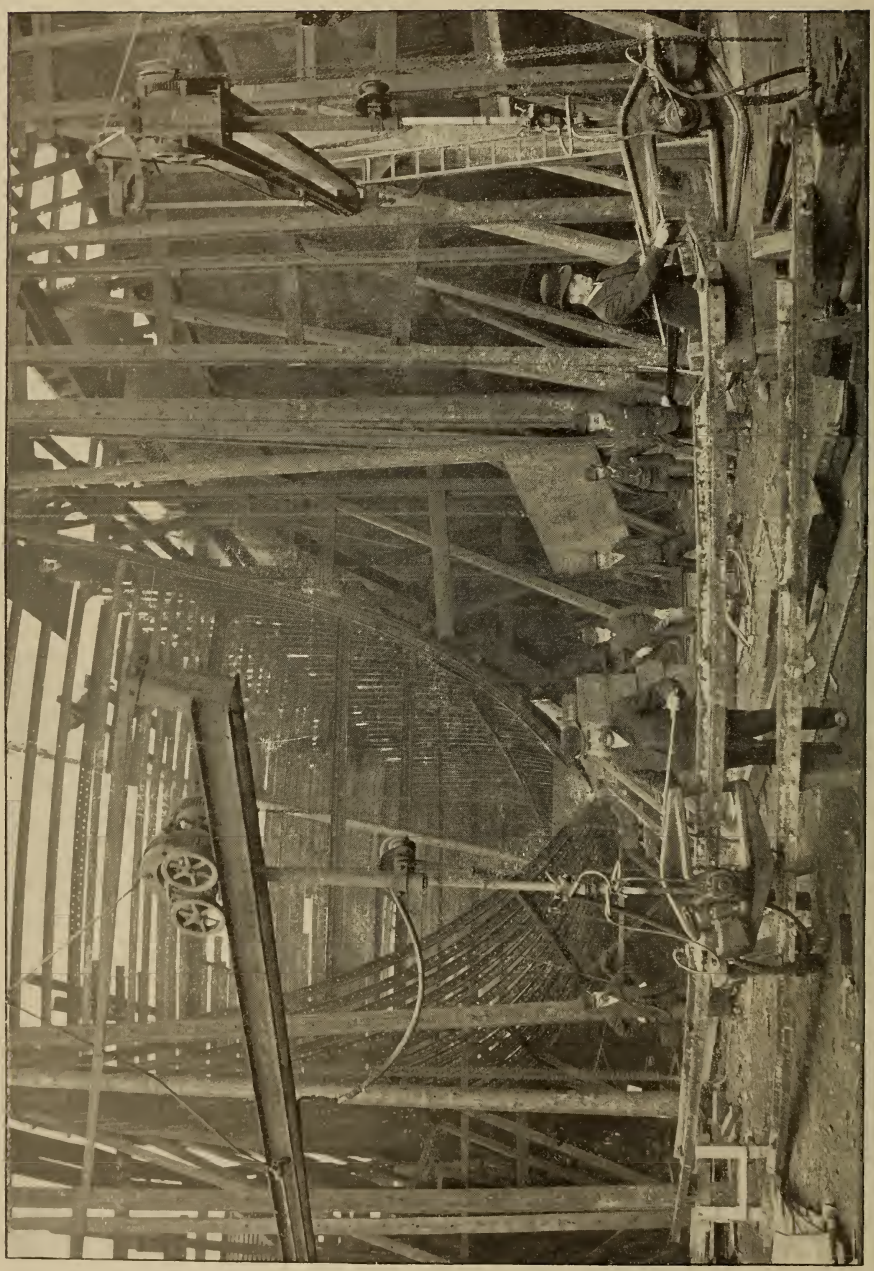
*By Ralph Hart Tweddell, M. Inst. C. E.*



THERE are few branches of applied mechanics so ancient as those connected with the use of water. One of several inducements held out by Moses to the Israelites to leave Egypt, was that they would no longer have to distribute water for irrigation and other purposes by working the well-known plank and bucket with their feet. But it is now held to be an advantage in many of the machines about to be referred to that they can be "worked by the foot" as well as by hand. There is little doubt that the adaptation of water to other purposes than that of irrigation and water supply would not have been left to the nineteenth century but for the prejudice caused by its unfortunate application by the heathen priesthood to opening and shutting the doors of their temples. The means by which the doors were thus worked being invisible to the worshipers, and noiseless, it was easy to ascribe their movement to divine power.

It may not be amiss to point out here what is generally understood by the term "hydraulic machine tools." Machine tools, to the popular mind, are more or less noisy, but ingenious, pieces of mechanism, consisting of many wheels and shafts, all revolving at different speeds, and compelled to do this by means of numerous pulleys and belts, which transmit the power required to drive them from a main power shaft driven by the works engine. The dangers to life and limb, and the loss of power due to this form of transmission are well known.

To obviate noise and, at the same time, to secure more efficiency in the transmission of the power given out by a prime mover, is the object aimed at in the application of hydraulic pressure to working machine tools, some of which are illustrated in the following pages. As in most other mechanical, and, indeed, all improvements, the system had a very small beginning, and, like Topsy, "it growed." Economy in transmission was, in the first place, never thought of, but only improvement in the quality of work. The first hydraulic tool consisted of a small machine for tightening the ends of tubes in marine boiler tube plates, and as the results were satisfactory, attention was naturally directed to other possible applications in connection with boiler work. One had not far to seek in the days of nearly thirty years ago to find these weak points in boiler construction. The riveting was then notoriously bad, preventing the use of higher steam pressures. Increased pressures meant thicker plates, larger rivets, and necessarily tighter joints, and as men did not

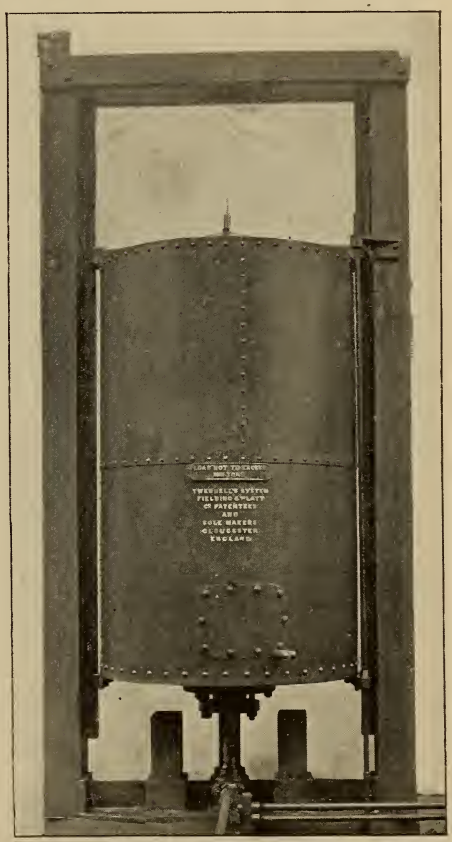


RIVETING UP A SHIP'S FRAMES BY HYDRAULIC MACHINERY.

increase proportionally in their size and strength, and as the limit of the power of the steam riveters had been reached, it was necessary to look out for some other means. The application of hydraulic pressure seemed to point to a satisfactory solution, and with suitable modifications a stationary riveting machine was designed, made, and started about thirty years ago. This was the precurser of thousands of such machines, not only for this purpose, but for punching, shearing, flanging, forging, drilling, bending,—for more purposes, in fact, than can be referred to here.

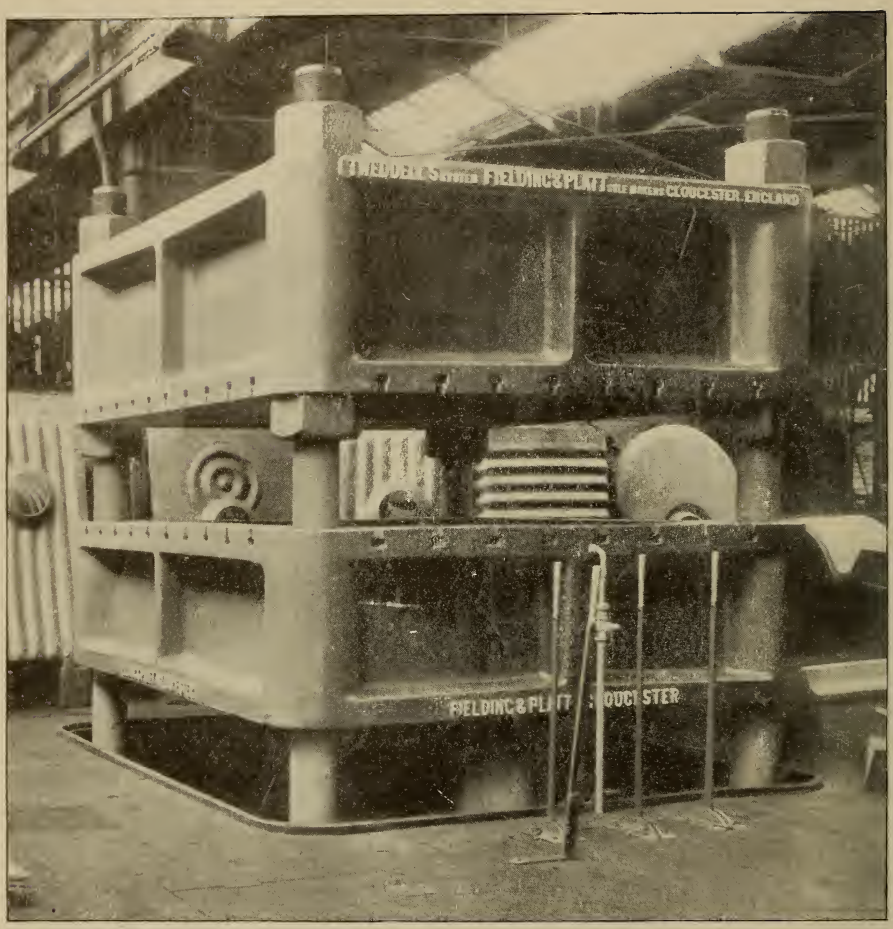
It was owing to the increased application of all these different machines that the economy of hydraulic transmission became apparent, especially in connection with machines worked intermittently and often at rest for long periods, but which, when at work, are often required to exert a very large amount of power through a small distance. Silent, often invisible, lines of pressure pipes replaced the noisy and obtrusive lines of shafting, and it became immaterial, so far as efficiency and economy were concerned, whether the machine was ten yards or ten thousand yards from the prime mover. But, it may be asked, how is the power of the prime mover applied to all these machines, spread over a large area, without shafting, and "wheels going round?" It is thus:—The steam engine or prime mover is, of course, still required, but, to do the same amount of work on the hydraulic system as it did previously, it need be only of from one-third to one-half the power. Attached to the engine is a set of pumps—if for a small plant, a set of belt-driven pumps—but even this small amount of belt transmission is preferably not used now, but, instead, some form of direct-acting duplex engine, varying in capacity from 5 to 120 gallons per minute. The water thus pumped is delivered into a high-pressure accumulator.

All engineers know what an accumulator is, but to the general reader it may not be amiss to explain that the pressure per square inch at which the water enters the mains, and at which all these hydraulic machine tools work is 1500 pounds per square inch. In order to obtain this pressure from an elevated tank or reservoir, the water would have to be pumped to a height of at least 3450 feet. Hills of such height are unfortunately not usually available near an engine works or boiler shop. Instead, therefore, of pumping the water to the top of a pipe 3450 feet high, it is



AN HYDRAULIC HIGH-PRESSURE ACCUMULATOR.

pumped into a cylinder of moderate area, and in order that the ram in this cylinder may not be lifted until a pressure of 1500 pounds per square inch is attained, it is weighted with heavy material. Water pressure is thus obtained by load instead of by elevation. Incidentally, another advantage is obtained by the use of this form of reservoir, namely, the automatic stopping



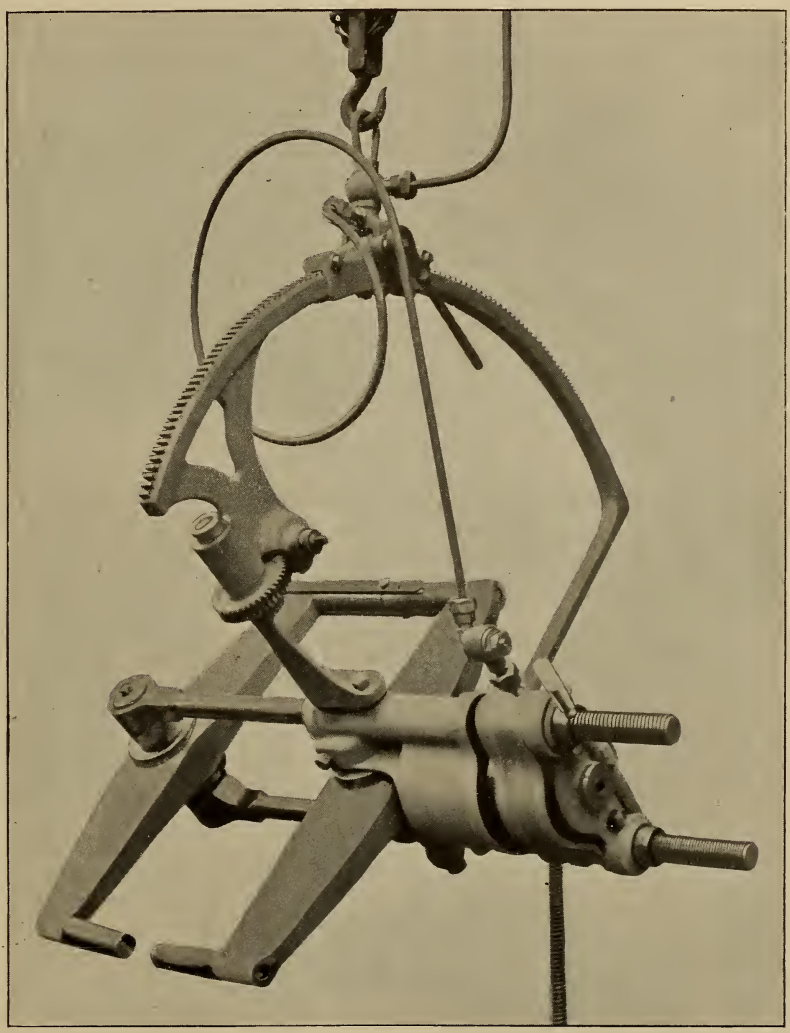

A 650-TON HYDRAULIC PRESS FOR FLANGING PLATES.

and starting of the pumping engines by the accumulator itself. Thus, when no work is being done, the engines are stationary and not kept always running as in the case of an engine and transmission by shafting. The effect of the accumulator is to permit of the use of a small pumping engine, running more or less continually, and storing up water so as to be ready for any sudden large demand, in exactly the same way that a provident person pays in, from time to time, small sums to his banking account, thus enabling him to meet a sudden call for a large sum without inconvenience.

Having provided pumping engines and accumulator, the next thing is to lay down a system of pipes for transmitting the power to each machine. This appears very simple on the face of it, but judgment and experience are required in fitting up a large works. For supplying stationary machines the work is quite straightforward; but there are also to be considered portable hydraulic machines for riveting, and these require special pipes and cranes. The stationary hydraulic riveters require the boiler, girders or other work to be brought to them, but when these pieces weigh many tons, it is impossible to do this economically. Yet more impracticable is it to bring a railway bridge, which has to be riveted in its final resting place, to the machine. This being the case, the only course left

open was to take the riveting machines to the work, and when this was done a new departure in hydraulic mechanism was inaugurated.

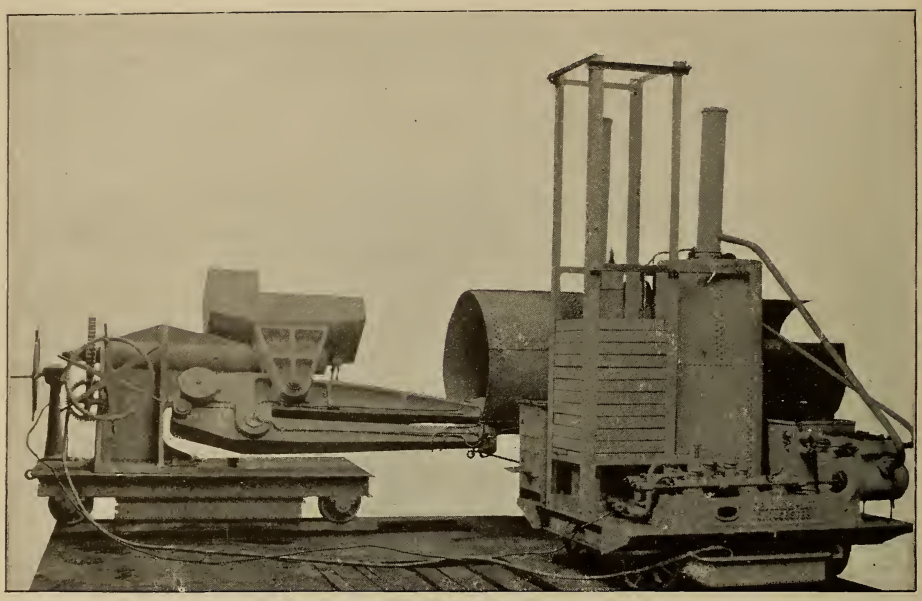
In order to fully appreciate the difficulties to be met in this application, it



THE FIRST PORTABLE RIVETER IN ACTUAL SERVICE.

is necessary to have some idea of the work to be done. To close ordinary girder rivets, a pressure of from 20 to 40 tons is necessary—that is to say, a weight, equal to a large locomotive without its tender, has to be put on the hot end of the rivet in order that not only a proper head may be formed, but, what is of much more consequence, that in many cases a number of plates may be brought into the closest contact, and holes, sometimes 8 or 10 inches long, may be closely filled up. In stationary machines the pressures exerted often amount to 150 and sometimes 200 tons for every rivet closed, and this sometimes at the rate of from 3 to 5 times per minute.

The first portable riveter, patented in 1871, was used to rivet ships' frames.



A "RIVETING TRAIN."

In the following year, and in 1873, the first bridge was riveted by this means "in sitü" on an English railway. Later on, these portable machines were used for riveting the frames and keels and other parts of the huge Atlantic liners; in fact, without the use of hydraulic riveting machines, such vessels would shake their rivets loose in a very short time. Hence, so far as is possible, hydraulic riveting is specified for frames and keels. The object now to be aimed at is to be able to rivet also the shell plating.

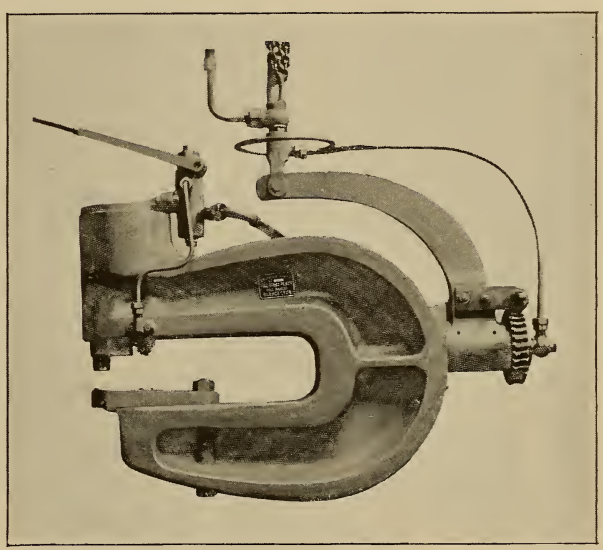
A LEVER RIVETER WITH CURVED CYLINDER.

To fulfill the various conditions met with, different types of portable riveters have been introduced from time to time. The original riveter was of the moving lever type, could rivet at either end, and was readily altered to suit diffferent sizes of work; but it was somewhat expensive to make, and not so well suited to heavy work as the direct-acting machine, which is really only a small stationary riveter, provided with

suitable suspending gear. But it was soon found that the cylinder was an obstruction to getting at rivets in corner work ; hence, in such cases levers were again adopted, though in a simpler shape. One end only of the lever was utilized for riveting, the other ends having attached to them a cylinder and ram. By boring this cylinder to a radius struck from the centre gudgeon, a very rigid connection was obtained, and riveters of great size and power are now made on this plan. Such machines, suspended to traveling cranes, illustrate another advantage of the use of hydraulic pressure for this class of work. Although termed "portable," in contradistinction to stationary machines, they often weigh several hundredweights, and in some cases even tons. If they had to be lifted by hand power they would be in many cases useless, but by using the great hydraulic pressure which works the machines to lift them also, two birds are killed with one stone.

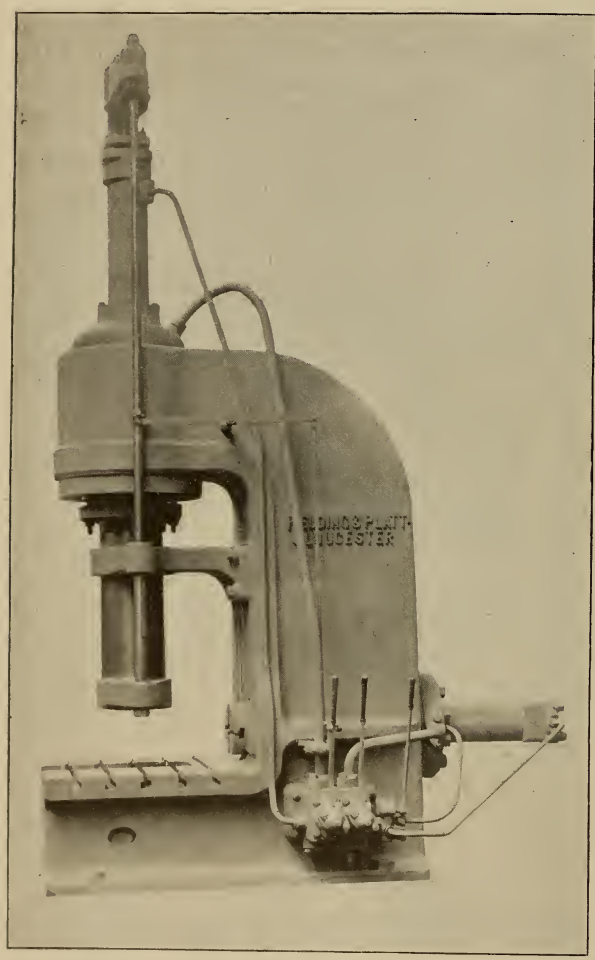
It is not at all unusual to see these portable riveters, or "spiders" as the men call them, exerting 30 tons pressure three or four times a minute, suspended some hundred feet in mid-air. Every one has heard of the great oil pipe lines. These are made of steel, and have to be riveted in sitü. In such cases a sort of "riveting train" is used. One truck carries the motive power, pumps, accumulator, etc., and another, the riveting machine. This plant is taken to the extreme point of the line and, as length to length is added to the main, it travels down with it, closing up each length as well as riveting the horizontal seams. Further illustration of the old proverb that, as the mountain could not come to Mahomet, Mahomet went to the mountain, is found in the application of these portable riveters to riveting up the back ends of marine boilers, or riveting in furnace mouths. Curious things are sometimes asked to be accomplished by hydraulic machines, and not the least so is the work done in riveting up the closing-in end of a boiler when both ends are in their place. At first sight it seems somewhat to resemble the class of difficulty experienced by the monarch who could not tell how the plums got into the pie dish with the crust on. However, it is successfully accomplished.

Riveting, however, by no means exhausts the application of hydraulic pressure to machine tools. Before the heavy plates of a marine boiler can be riveted, they have to be bent to shape, generally circular. Hitherto this has been done by passing the plates through rolls, but, for many reasons, especially in the case of thick plates, machines on this principle would have to be made of enormous strength and size to prevent break downs, and even when the plate had safely passed through, it was not finished to a true curve at the leaving end. These disadvantages are overcome by the use of the hydraulic bender. In this machine the plates are simply drawn between two dies, the



A DIRECT-ACTING PORTABLE RIVETER.

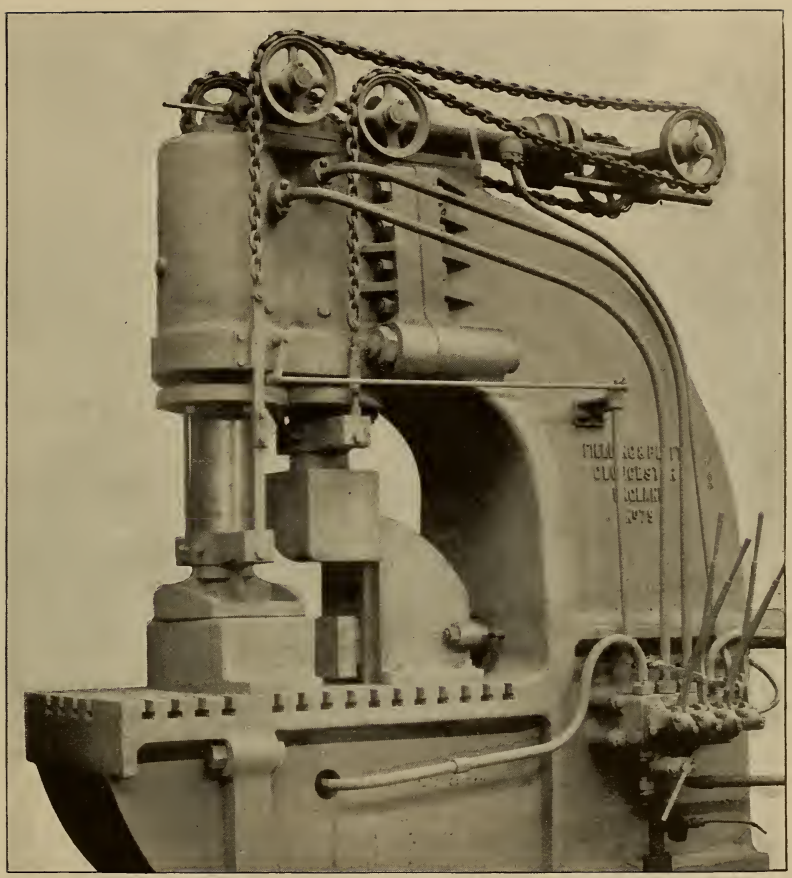
lower one moving up at each stroke to the exact distance required to give the true radius. A breakdown is impossible, since the machine cannot be "overfed" as it is termed. In fact, this is a great merit in all hydraulic machines. As the pressure of water is constant, the maximum power which the machine is designed to exert cannot be exceeded, and the exact pressure is always known, a very important matter, especially in riveted work. In the case of a boiler, not only have the plates to be bent, but they must also be flanged. This process, when done by hand, requires the highest class of skilled labor and involves very hard work.



AN HYDRAULIC FORGING PRESS.

One of the many advantages of the hydraulic system is, that it releases men from work of a most laborious kind. One of the largest flanging presses is that illustrated on page 58, and located at Crewe, England. This machine exerts a power of 650 tons and, in common with all similar machines, finishes the work off in one heat; and as everything passes through the same dies, the products are all identical and interchangeable. Such machines represent another step toward insuring tight boiler work, for no mere increase of pressure on the rivet will make tight work if the flanges and plating do not accurately fit each other to begin with.

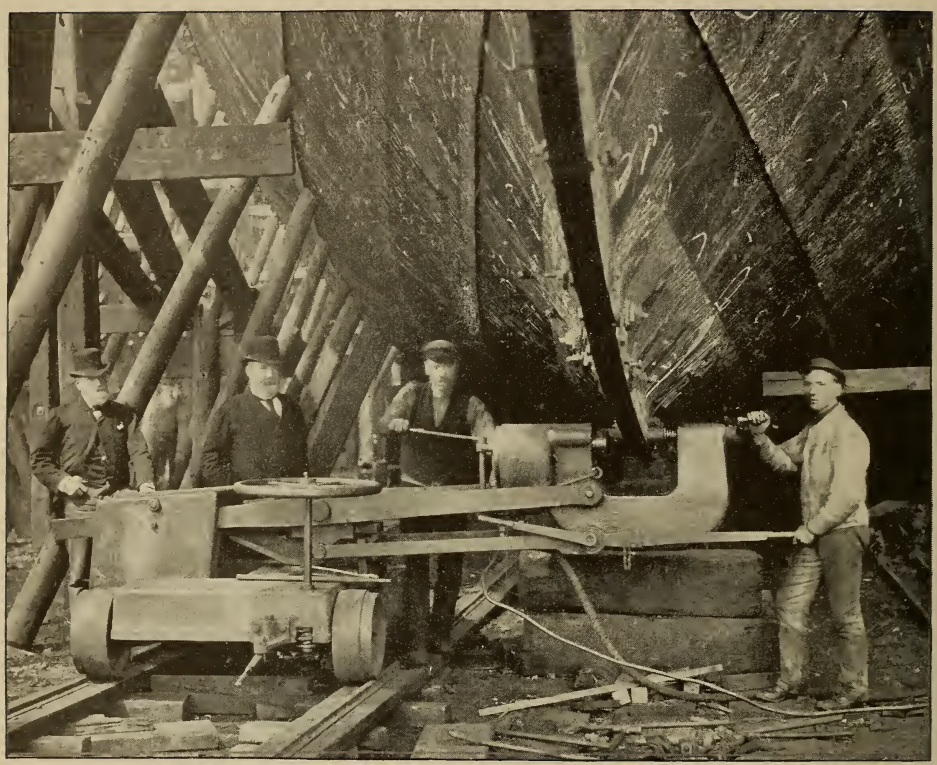
Powerful as the above press is, it is not equal to doing marine work of the heaviest class, and when presses are made equal to this, their cost and that of dies is enormous. It is a well-known fact, that no consulting or marine engineer, with a proper feeling of self respect, will alter his dimensions $\frac{1}{8}$ inch or even $\frac{1}{16}$ inch to please a boiler maker, who may already have dies and blocks so near to what he wants. Hence, the cost of providing dies, to suit all purchasers, becomes prohibitive, and a machine working on a totally different principle was introduced. Instead of having dies and blocks of the full size of the work to be done, say a circular boiler end, 14 feet or more in diameter, a small segment of a circle only is used, and the plate, having been suitably centred, is turned round, and, having



A "STEP BY STEP" HYDRAULIC FLANGING MACHINE.

been tightly seized and held in place on this segment by one ram, another one descends and turns the flange over. To complete the operation and square this flange up, a third ram comes forward. The machine, in fact, follows, as closely as may be, the method practiced by hand, but instead of the countless blows of many hammers a pressure of from 50 to 100 tons quietly does the work in one movement. Special machines are also used for bending ships' keel plates and flanging many parts of similar structures, thus dispensing with angle and tee irons and other complications.

The next attack by the hydraulic pressure system was on the steam hammer. This battle is still going on. In the other applications victory has been achieved, and in time, probably, the same will be said of the application to forging and stamping. It may be taken that the practical employment of the hydraulic forging-press dates from the successful production of steel in the form of large ingots ; and, as in its day, Nasmyth's steam hammer superseded machines of less power, so the former will have to give place to the hydraulic press. Much has been written as to the relative merits of the steam hammer and the hydraulic press, but while there is room for difference of opinion in reference to work of ordinary dimensions, there is none when it comes to a ques-



HYDRAULICALLY RIVETING UP THE KEEL OF AN ATLANTIC LINER.

tion of making the heavy forgings now required for large guns and marine shafting, and the hydraulic press shows to greater advantage as the work to be dealt with increases in weight and complexity.

The introduction of the hydraulic forging press is due to Mr. M. Gledhill, managing director of Sir Joseph Whitworth & Co. About the years 1860–61, the firm in question had considerable trouble in obtaining steel suitable for the manufacture of guns. So far as the art of steel manufacture was then understood, nothing could be alleged against its quality. It was this which suggested to Sir Joseph Whitworth the idea of subjecting this material to a very high pressure when in a fluid state, his notion being that this compression could be applied not only to ingots, but to castings of all shapes. This, however, was found not practicable, and it was then that Mr. Gledhill suggested forging the ingot after compression in a suitable hydraulic press. Putting aside, however, these large presses, there is a considerable field open for machines exerting something less than 10,000 tons at each blow or squeeze. Small presses are now used in leading railway and other works, and in wagon building; especially at Swindon, in England, most interesting work in welding, stamping and forging is accomplished.

The author would acknowledge his indebtedness to Messrs. Fielding & Platt, of Gloucester, England, for the use of the photographs of the machines illustrated, in connection with the manufacture of which their name is so well known.

# THE FIRST IRON CASTING IN AMERICA.

*By Albert Spies.*

AMONG the riches of mineral wealth and the products of the metallurgical arts in the Mining Building at the World's Columbian Exposition, in Chicago, there was not anything which attracted more serious interest on the part of those acquainted with the founding of metals, than a modest glass case in the gallery of the building, containing a tiny iron kettle, of about one quart capacity, swinging on a miniature crane. The cause of this attraction was not due to any peculiarity of design or material, or skill in workmanship, but to the fact that the kettle was well authenticated as the first casting made in America and the precursor of the vast iron industry of the country.

The kettle was cast at the Saugus Iron Works at Lynn, Mass., in 1642, probably in the autumn, and was given to Thomas Hudson, as the consideration for sixty acres of land, comprising a portion of the iron works property. This Thomas Hudson was, undoubtedly, the younger brother of that name, of Henry [Hendrik] Hudson the eminent English navigator. The kettle was kept as an heirloom in the direct descent from Thomas Hudson for over a century, when it passed into the female line, and thence back into the possession of John E. Hudson, Esq., of Boston, a direct descendant, who presented it to the city of Lynn a few years ago.

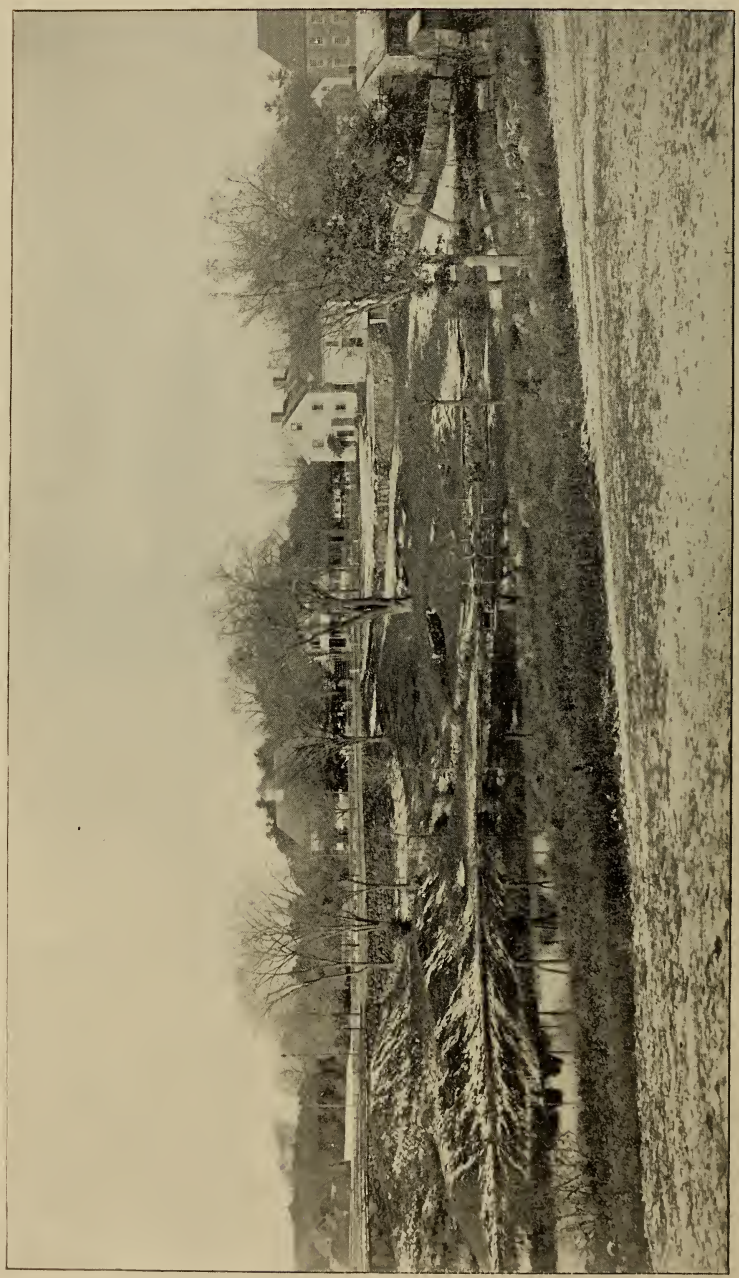
A number of the citizens caused it to be placed in a suitable case, with a tablet, and it is now kept in the City Hall. The city Government authorized its exhibition at Chicago last year in response to a special request from D. W. C. Skiff, chief of the Department of Mines and Mining, and the jury in that department awarded a medal to the municipality for this unique exhibit.

It may be very naturally asked, what is the evidence warranting the presumption that this kettle is, as claimed, the first casting made at the Saugus Iron Works?

There are still living persons who formerly owned the kettle and remember the story of its origin, as told them by their grandmother who had, in like manner, received its history from her grandfather,—the son of the original owner. It is true that this article lacks the stamp and attested record of many witnesses, but, like Plymouth Rock and many other important relics of American history, it depends in part upon tradition in a generation devoid of sentiment or personal interest, which might introduce possible elements of error. Tradition has preserved for the world much of its history, essential principles of law, and even vital points in both Jewish and Christian religion.

The design of the kettle is that of a type used in the earliest colonial days, but in its physical characteristics it bears evidence of being made of iron cast directly from the ore as reduced in a blast furnace, and not from pig iron remelted in a reverberatory or a cupola furnace; and there is no evidence or reason to believe that there was either of these furnaces at the Saugus Iron Works. The registration of deeds of land did not begin in the colony of Massachusetts Bay until a later date, and there is no evidence bearing on the subject, to be obtained from that source.

The first published record of this kettle is contained under date of 1642, in the history of Lynn, by Alonzo Lewis, 1844. The same is included in Lewis's and Newhall's History of Lynn (1890), and is referred to in



THE SITE OF THE FIRST IRON FOUNDRY IN AMERICA, ESTABLISHED IN 1642.

every history treating of the Saugus Iron Works. The Standard History of Essex County, C. F. Jewett (1878), of which the chapters upon Lynn were prepared by the late Cyrus Mason Tracy, contains a description of this kettle, and there is extant a manuscript written by Mr. Tracy, in 1881, in which that able antiquary eloquently referred to the kettle as "the humble prototype of the immense iron industry that now extends over our land."

Further references on this subject may be made to Volume I. of the History of Essex County, Massachusetts (J. W. Lewis, Philadelphia, 1888), in which the chapters on Saugus were written by William F. Newhall, Esq., of Saugus.

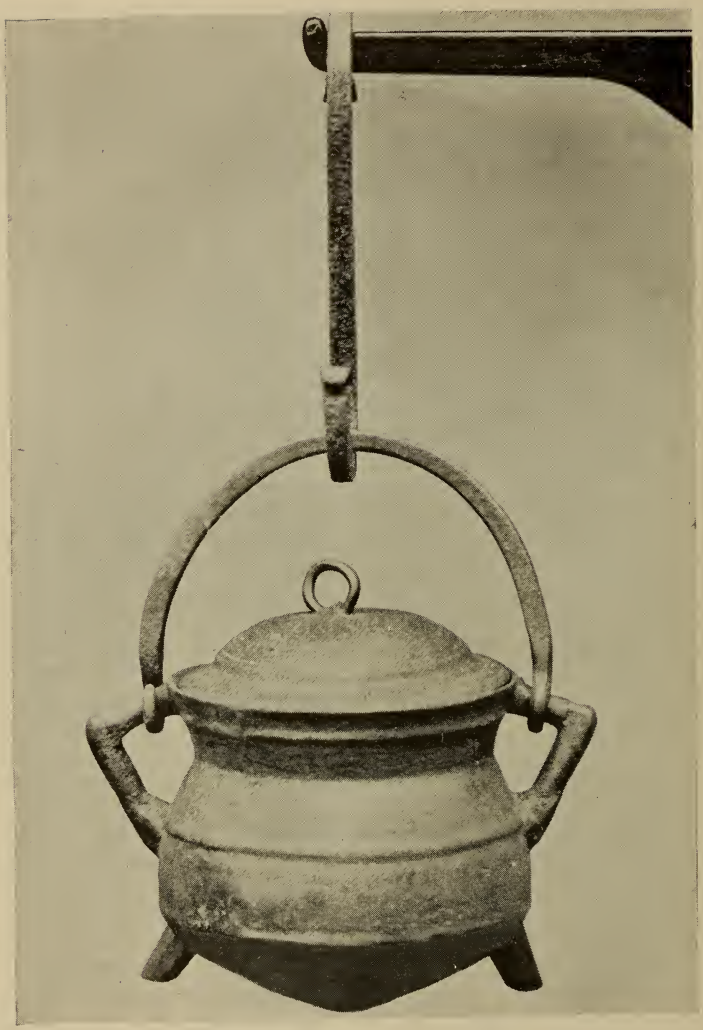
Much of the information respecting this early establishment is obtained from an address by Mr. C. J. H. Woodbury, contained in a monograph on the Saugus Iron Works, published by the city of Lynn on the occasion of the presentation of this kettle. The Saugus Iron Works were such an important factor in the inception and early development of American industries that their early history merits due consideration. This was not the first attempt at iron smelting, but the first success. The expectancy for mineral wealth was universal among the early explorers of America. Every royal character, patent, grant or commission contained exact provisions for the division of precious and base metals, in which the privy purse was to share largely. The avaricious Spaniards expected gold, and abased Columbus because he had not found it in fabulous plenty. The later Spanish explorers pillaged enough gold in Mexico and Peru to trample out the Aztec civilization, and, in turn, ruin themselves.

The outline of the Western Atlantic littoral had not been fully established before Spanish romancers pictured the unknown lands with strange peoples, who submissively yielded to the conquerors, and bestowed upon them a plethora of precious metals. The thrifty English were not blind to the attraction of mineral wealth, and sought the less alluring but more valuable iron, although that metal was unknown to the Indians, save in a few instances recently discovered by Professor F. W. Putnam, where the mound builders fashioned meteoric iron into ornaments or implements.

The earliest reference to iron ore in America is contained in the History of the Second Expedition to Virginia, by Thomas Harriot, in 1586, wherein he says in reference to Roanoke Island :— "Wee founde neere the water side the ground to be rockie which by the trial of a mineral man was founde to hold iron richly. It is found in manie places of the country else." The hostility of the natives was so intense that the colonists soon returned to England without developing the mines.

The Jamestown colony mined and sent iron ore to England as early as 1608. In 1622, they built iron works at Falling creek, a tributary of the James river, about seventy-six miles from Jamestown, for the purpose of reducing bog iron ore. The works had approached completion, when the Indians attacked the settlement, killing 350 persons and burning the buildings, March 22, 1622. Thus the enterprise, for which skilled men had been especially sent to the Jamestown colony from England, was abandoned. The Massachusetts Bay Company, at a meeting in London, March 2, 1628, considered the advisability of sending Malbon to New England to prospect for iron ore, and he was at Salem in 1629, but it is not known that he ever reported any discoveries.

The bog iron deposits in the upper Saugus meadows were discovered by Thomas Dexter, one of the colonists, and he informed his fellow townsman, Captain Robert Bridges, who went to London and formed the Company of the Undertakers for the iron works, which was started under the management of these two men, with Joseph Jenks, one of the best workmen of the day, as master mechanic. Captain Robert Bridges was one of the leading men of the settlement, having been entrusted with diplomatic offices on the



AMERICA'S FIRST IRON CASTING, 1642.

part of the colony of Massachusetts Bay, and of whom it was said by Nathan M. Hawkes, "No man who lacked suavity and winning social manners could have persuaded calculating London merchants to have ventured their dearly loved funds in an iron works experiment across the Atlantic in a savage and unknown land."

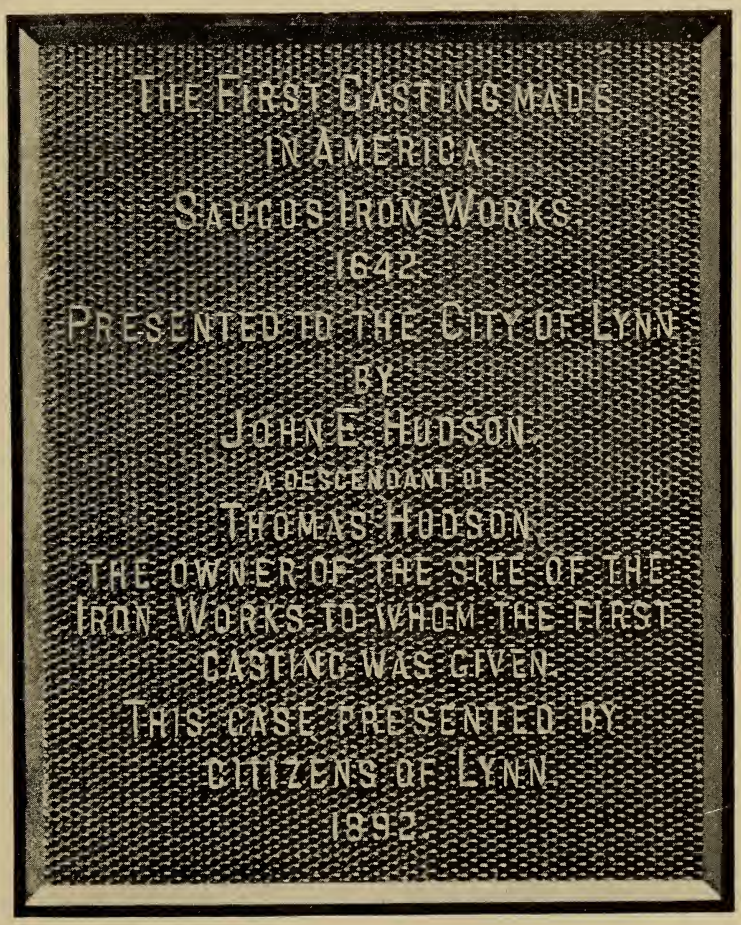
The site of the iron works was well selected, being situated at the head of navigation, by the ford in the highway from Boston to Salem, at a water-power, and near to the bog iron ore deposits, whose exact location is unknown, save that they were in Adam Hawkes' meadows. The whole iron works tract probably covered 3000 acres. The General Court granted them at various times immunity from import or export duties, and from taxation, and other privileges. The act of October 14, 1645, is probably the earliest instance of legislation upon the principles of protection to manufacturers, which has been such an important feature in the

development of American industries. The act is a long document, but the following extracts are of especial interest :—

"5. * * They shall have free liberty to transport the same (their iron) by shipping to other parts or places of the world, and to make sale thereof. * * * Provided they sell it not to any person or State in actual hostility with us.

"7. It is also granted that the undertakers and adventurers, together with their agents, servants, and assigns, shall be and are hereby free from taxes, assessments, contributions, and other public charges whatsoever, for so much of their stock and goods as may be employed in and about the said iron works, for and during the period of twenty-one years yet to come from the date of their presents."

There is not any detailed description of the works and the exact methods employed, but there is much light thrown upon these matters in the voluminous records of continual legislation and litigation, which took place during the forty-six years that the works were in operation. The works contained a blast furnace, in which bog iron ore was reduced by means of char-




TABLET FORMING THE BACK OF THE GLASS CASE IN WHICH THE KETTLE SHOWN OPPOSITE IS KEPT AT LYNN.

coal, using as a flux lime, which in the earliest days of the works was obtained from the oyster shells which then abounded on the coast of Massachusetts Bay. Cannon were also melted at this foundry, far in advance of the time when swords were to be beaten into ploughshares, or spears into pruning hooks.

The iron from the blast furnace was run into straight trenches in the sand, and thereby cast into long triangular bars called "sowe iron," which were converted into wrought iron and steel. The wrought iron and steel were made in a bloomary, which may be described as a charcoal fire, four feet thick, in a blacksmith's forge. The end of a bar of sow iron was plunged into the fire, and in time a pasty mass of wrought iron would settle to the bottom. Other portions of the bar would be converted into steel when the process stopped at the intermediary stage between cast and wrought iron. This process of steel-making is still used throughout the Oriental nations, and also in the mountainous region south of the Ohio river.

Castings were made directly from the metal flowing from the blast furnace into a pool, whence it was dipped by crucibles and poured into molds. The cupola furnace was not invented until 1790.

The manufacture of wrought iron and steel must have been entered upon contemporaneously with that of cast iron, as John Endicott, of Salem, the first Governor of Massachusetts Bay, wrote to Governor John Winthrop, at Boston, December 1, 1642:—"I wish to hear much of your son's iron and steel," the son being John Winthrop, Jr., who was interested in the Saugus Iron Works.

The iron works also included a machine shop, from which the first fire engines in America were built for the town of Boston, in accordance with a vote of the town meeting, March 1, 1654, that "the select (men) have power and liberty to agree with Joseph Jynks for ingins to convey water in case of fire, if they see cause so to do." Although the works were in operation very soon after building was commenced, yet additions were made during a number of years. In 1645 an order of the General Court shows that the works had "some tons of sowe iron cast and some others in readiness for the forge," and letters of Governor Winthrop in August and September, 1648, state that the furnace produced seven to eight tons per week. The principal product was bar iron "as good as the Spanish," costing £20 per ton, also axes and agricultural implements.

When Governor John Endicott began the Oak Tree and Pine Tree coinage in 1652, the dies were made by Joseph Jenks at the Saugus Iron Works. It is stated by Judge James R. Newhall that the designs were made by Elizabeth, the wife of Joseph Jenks, the master mechanic. This coinage, bearing the stamp "Massachvsetts State," without any reference to the throne, was probably the first fundamental act of independence to the mother country. The colonists were driven to such a course by the lack of money, as exchanges were for the most part carried on in barter with bullets and wampum serving for small coin. Joseph Jenks also invented a saw mill, which received a patent for fourteen years from the General Court, on June 10, 1646, being the first patent granted in America, and also a water engine for mills, which was undoubtedly a form of water wheel and not the hydraulic engine which that term would now signify. He also invented the modern American scythe, long and narrow and stiffened by a ridge along the back, a marked improvement "for the more speedie cutting of grasse" over the broad, short bushwack scythe made from a thin plate of steel, and richly deserved the patent for seven years which was granted by the General Court, May 23, 1655. In 1667 he petitioned the General Court relative to a wire manufactory, and May 15, 1672, his petition for authority to coin money was refused.

The litigation to which the iron works were subjected increased and became oppressive. It appears as if the im-

pulse to "sue the corporation" was instinctive among the townspeople. The corporation, its managers, and its workmen were proceeded against under every conceivable excuse. The boundaries of worthless land, poor crops on sterile soil, unrestrained courtships, speaking lightly of the Governor, reproachfully of the church, and harshly of the King, were all subjects of long-continued and bitter litigation.

Land was sold to the corporation, and afterward further damages claimed. Dexter brought suit because the alewives did not come into his net below the dam as of yore, and Hawkes sued because the water rose too high above the dam. The town sued the corporation for pew rents in the meeting houses several miles distant, and notwithstanding the immunity in the act of October 14, 1645, already quoted in part, won the case. The pews could not have been worn much, for the courts took action against the managers for not attending public worship.

The works are not known to have been in operation after 1688, when the tract had diminished to 600 acres and passed into individual ownership. If the supply of bog iron ore had been sufficient for the works, they would undoubtedly have been continued the same as other enterprises of that day in various parts of New England.

The immediate return to those engaged in the enterprise is now of little moment, but the results to the whole colony of an establishment which attracted, developed, and then scattered a body of skilled mechanics, were of great importance, and, no doubt, may have been an essential factor in rearing many prominent industries. The grass-covered mounds of ashes and dross along the banks of the Saugus river are the only vestige of those busy works, and serve as an uninscribed monument to the mechanical pioneers of America.

# ENGLISH AND AMERICAN SHIP-BUILDING.

*By J. S. Jeans.*

NO recent economic or industrial movement in the United States appears to have attracted so much attention in Europe as the remarkable advances made in shipping and ship-building, and the revival at all the principal ports on the great lakes as well as on the seaboard, of what appeared until quite recently to be a decaying, if not an absolutely defunct, industry.

This development has found visible and manifest expression in the growth of a new American navy, which has come into being with an amount of vigor and enterprise, which is rare even in the economic and naval annals of the most enterprising countries. Not content with having built within a very few years a navy which could give a good account of itself in any naval engagement, except perhaps with the unique and still unmatched naval power of the mother country, American ship-builders have been laying themselves out for undertaking work for other powers, and they have quite recently, through one of their most prominent representatives, offered to compete with British ship-builders for British work, much to the amusement of ship-builders on the Tyne and the Clyde. The Americans have, however, done a good deal more than this. They have acquired the two crack vessels of the Inman line, the Paris and the New York, which they are now sailing under the American flag, and they have undertaken the construction of companion ships to these noble specimens of British naval architecture which are likely to be equal to them in every way. The development of the ship-building industry on the lake ports and the building of such noble and unique craft as the Christopher Columbus for the Chicago Exhibition traffic, the Priscilla for the Fall River line, and the new passenger steamer North-West for the lake traffic, are all stepping-stones on the march of progress toward a higher order of things, which may well inspire American ship-builders with hope and courage for the future.

The history of the development, decline and fall of the American ship-building industry has been told so often, in one form or another, that it is tolerably well known even to the man in the street, not to speak of those whom the record specially concerns. When Great Britain had demonstrated by the building of the Great Eastern and other ships of still earlier date that iron was to become the material of the future, American ship-builders could not but admit that their day was over, and that, while they could compete with any other country in timber constructions, they were virtually out of the race when it came to iron and steel. At that time American iron was a very costly product, and it did not appear for many years that it could ever be brought within reasonable distance of the prices that ruled in the mother country. The Baltimore clipper and other well known types of American vessels consequently went to the wall. They died very hard, however, and made a stout fight to the last.

Before the war the merchant marine of the United States was of even greater magnitude than that of the mother country. The tonnage of the American register in 1860 was 5,289,000 tons, while that of the United Kingdom was

only 4,658,000 tons. The war came in at this stage of the competition and did a great deal to destroy the chances of the United States. In 1859 American ship-builders turned out nearly a hundred thousand tons less than they had done in the previous year. In 1862 they constructed nearly 60,000 tons less than they had done in 1861. Between 1860 and 1866 the tonnage of ships engaged in the foreign trade on the American register fell from 2,496,000 to 1,387,000 tons. In the same interval the tonnage of vessels on the British register rose from 4,658,000 tons to 5,500,000 tons. England continued to more than maintain this lead by giving up wooden ship-building and going almost wholly into iron and steel. In the United States, on the contrary, up to within the last five years the tonnage of iron vessels constructed did not, except in one particular year, exceed 45,000 tons per annum.

Congress was requested at one time to declare bounties, at another time to subsidize American tonnage with heavy mail subsidies, at a third time to shut out British tonnage, and at a fourth time to make American ship-building a specially protected industry. But all was in vain. The attempt to compete with Great Britain in ocean navigation was again and again attended with disastrous failure. The history of the well-known Collins line was the culmination of a long series of failures and disasters. Thenceforth America appears to have relinquished the struggle, although never with good grace, until it was recently revived with the inauguration of the American line, and the building on American waters of vessels that were pronounced to be fit to compete, on their strict merits, with the best productions of English ship-building yards.

It is of the utmost importance to both countries to ascertain whether there is a reasonable hope that the newly-awakened impulse to American ship-building is likely to be founded on such altered economic conditions as to seriously threaten the hitherto almost undisputed supremacy of Great Britain in reference to both the building and the navigation of ships. But in order to bring home more clearly the actual facts upon this subject, we must to a certain extent go back to the past.

The decline of American ship-building was a function of the decline of American shipping, and both alike received attention at the hands of the United States Government at an early stage in their history. As Secretary of the Treasury, in the year 1866, Hugh McCulloch took a great deal of interest in this matter, and had a special report made upon it by the director of the Bureau of Statistics, which was referred for consideration to Mr. David A. Wells, then special commissioner of revenue. In this report it was pointed out that the American "commerce upon the high seas, at one time so potent a means of acquiring national wealth, and at the same time of exhibiting to the world a proud indication of our growing strength and spreading influence, has fallen to so low a point that, while in the year 1853 it was fifteen per cent. greater than that of Great Britain and maintained a close competition with it up to the year 1861, it had fallen in 1864 to less than half as much, and is now probably not over a third." It was pointed out at the same time that while in 1860 two-thirds of American imports and more than two-thirds of American exports were carried in American bottoms, in 1866 nearly three-fourths of the American imports and over three-fifths of American exports were carried in foreign bottoms.

The principal cause of this remarkable decline was attributed to the pressure of taxation. It was shown that in the building of a ship of 1223 tons the total cost would probaby be $96,650, and that of this amount labor would count for $25,100, wood for $26,950, iron for $12,400 and taxes for $2100. It was estimated that it would be necessary to reduce the total amount by $28,162 in order to bring down the cost to what it would be in the British provinces at that time. As an example of the serious character of the imposts levied on American ship-builders, it

was stated that "the iron carries with it taxes from the time it leaves the blast furnaces—taxes, too, repeated at every phase of its varied progress—until it is finally wrought into the spikes, nails, screws, shackles, chains, hawsers, capstans, sheet rings, marlin spikes and belaying pins of a ship." One ship-builder at that time gave evidence that he built in 1864 a vessel that cost $136,000, of which $25,000 was paid in taxes of various kinds. Another declared that while in 1856 he had built a first-class ship, fully equipped ready for sea, at $60 a ton, it would cost from $85 to $100 a ton to build the same vessel in 1864. Another ship-builder attributed the decay of the American ship-building industry to the high prices of labor, while another gave an interesting comparison of the prices of ship-building materials before and subsequent to the war, from which it appeared that timber had risen from $9 to $17 per ton, iron from 2½ to 5¾ cents per pound, and skilled labor from $1.75 to $3 per day, while sails and rigging had advanced to about three times as much as the prices before the war. Some other leading ship-builders computed that the cost of building an iron ship at that time would not be less than £25 per ton, a figure that compares very strangely with the £7 per ton, at which a large amount of steel tonnage has recently been constructed on the Tyne, the Tees and the Wear.

The action taken by the United States government in reference to tariff legislation and taxes generally, is a matter of national history upon which it is unnecessary to enlarge. Suffice it to say that the remissions made were not sufficient to render any material assistance to the ship-builders of the United States in building for foreign trade. On their own waters they were, of course, protected by the navigation laws, which excluded foreign competition. But the continuance of the depression in ship-building formed the subject of a special inquiry by the tariff commission of 1882, when the late John Roach, the sturdy and persistent, although finally disheartened and utterly vanquished, champion of iron ship-building in the darkest days that it had ever known, gave some important testimony as to the economic circumstances of the United States in comparison with those of Great Britain.

According to John Roach, "the English statesmen of that day saw that with a powerful fleet of swift iron steamers England could run away from the wooden sailing ships, secure the world's mails, passengers and first-class freights, and far more than regain what she had lost on the ocean." Such a fleet in the United States required rolling mills, engine work, extensive yards. To bring these into existence there must be an outlay of millions of capital. The wooden ship-builders, according to John Roach, could not meet these new and expensive requirements, nor were private capitalists willing to invest the vast sums of money requisite. In these circumstances the British government gave contracts to private ship yards to build iron steam vessels for the navy, and thus "the private builders were enabled to establish the great ship yards which have realized for England all that was hoped for them."

So much for John Roach, whose personal connection with iron ship-building is one of the most interesting episodes, if not also one of the most mournful, in the history of that industry. When almost every other builder in the United States was working on the old lines of wooden ship-building, Roach boldly came out of the crowd and arrayed himself on "the side of the angel," in so far as the better material was typified by iron. For many years he carried on this struggle, almost single-handed, without subsidy from the government, and without the encouragement vouchsafed to English shipbuilders in the form of occasional government contracts. At last there came a revolution in American naval affairs. About 1886 a new navy was resolved on, and the leading shipbuilders of the country were called upon to put forth their utmost skill and experience to furnish ships worthy of the nation and the period. They have not failed to respond to the call. The

show of models and war materials at he Chicago Exhibition of 1893 was a remarkable testimony to the acquisition of a rare amount of the highest skill and knowledge in a strikingly short space of time. The naval architects and the marine engineers of the United States have, within the last four or five years, produced vessels of every kind of which any nation might well be proud, and which constitute, in themselves, an imperishable monument to the energy, the aptitude and the resource of the American people.

But the utmost knowledge, the utmost skill and the utmost enterprise, however vigorously and wisely applied, will not enable a country to attain to high rank among ship-building nations unless there is allied to these essential qualifications the determining consideration of cheap production. It is from this point of view that American arsenals and ship yards have been behind in the past. What are they likely to do in the time to come?

Ship-building costs are primarily ranged under two main heads—materials and labor. A country that is handicapped in regard to either is likely to find itself at a serious disadvantage. How much more serious is the disadvantage experienced by a country unfavorably situated in reference to both; and yet, this has hitherto been the situation of the United States. Until quite lately, at all events, the American people could not command ship-building iron and steel without paying about double the prices paid in Great Britain. The main reason for this fact was probably the limited extent of the demand. Until comparatively recent years, the United States did not produce ship plates worth speaking of. There was practically no demand for them, the total annual ship-building iron tonnage being usually under 35,000 tons a year. Similarly with ship-building labor, which was employed in iron construction only on a limited scale. John Roach told the tariff commission of 1882 that he employed, altogether, about 3000 workmen—1000 in the city of New York and 2000 more at Chester, on the Delaware; but these were, of course, engaged in all branches of ship-building and marine engineering as well, and outside of Roach's works there was, for many years, but little demand for, or command of, ship-building labor in iron and steel. Of course, labor that is in any way exceptional has to be paid exceptional rates, and even at the present time, when such labor is much more plentiful, the average rate of wages is about twice that paid in England.

On the face of these figures, it appears to be ridiculous to expect that the United States could ever compete with Great Britain in the manufacture of ships and of ship equipments, such as engines, boilers, electric light machinery, etc. This, however, is an appearance only, and it is manifestly quite as obvious in relation to locomotives, elevators and other special productions of the United States, as in relation to steamships. And yet, as all the world knows, the United States have competed successfully with Great Britain in many outside markets in the locomotive business. Here, indeed, we have a parallel which is in many respects complete. A locomotive, like a modern steamship, is a highly complex and costly machine. It involves a great deal of highly finished mechanical work; it brings into exercise the highest skill of the designer, the builder and the artisan, and yet, as we all know, American locomotive engines are being increasingly built for foreign markets, and may be found all the world over, from "Greenland's icy mountains" to "India's coral strand." If the relatively high cost of labor were prohibitory, this could not have happened, even when we have allowed a large margin for the differences of design, which causes the American locomotive to be preferred in some cases regardless of price.

The evidence in reference to other branches of American industry, therefore, justifies the statement that high wages do not necessarily mean dear production, and that the payment of a

high scale of wages is not necessarily incompatible with pre-eminence in the industries that are chiefly responsible for the maintenance of national prosperity. Had high wages combined with a high cost of materials, the case would have been different. But within the last two years the United States have witnessed a truly marvelous change in this respect. Until that time the principal materials required for steel ship-building were almost double the cost of the same things in Great Britain, but now we find that the Carnegie and other companies are supplying plates, angles and other building materials to shipbuilders on the Delaware almost, if not quite, as cheaply as they can be purchased on the Clyde or the Tyne. I believe that sales have recently taken place at about £6 per ton, and this, of course, applies equally to all the other fittings in which iron and steel are largely employed. This is a very different state of things from that which formerly existed. John Roach told the tariff commission of 1882 that in the year 1872, when he undertook to build some large iron ships, the rolling mills did not exist in the United States that could make the angles, plates and beams required, so that he had to go to England for them, and pay £12 10s. for plates, £11 10s. for angles, 20s. per ton freight and 5 per cent. commission. It remains to be seen how far the fall of prices in the United States will affect the future of British ship-building, but if the American tariff is to be modified from time to time, as some expect, until it becomes a revenue tariff only, we may depend upon it that the cost of labor in American ship-building yards will eventually become accommodated to the necessities of a pan-American ship-building policy.

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## W. CAWTHORNE UNWIN.

PROFESSOR WILLIAM CAWTHORNE UNWIN, whose portrait appears in this issue, ranks to-day as one of the best known engineers, authors, and teachers of engineering science not only in England, but in America as well.

He was born at Coggeshall, England, in 1838, and after leaving the City of London School, became, in 1855, an apprentice in the well-known establishment of Sir William Fairbairn at Manchester. During this time he assisted Fairbairn in carrying out various researches on the strength of iron and steel, the density of steam, the collapse of boiler flues, etc. After this, he was, for some years, manager of engineering works, and in 1868 was appointed instructor at the Royal School of Naval Architecture, South Kensington, which position he held until 1872, in which year he became professor of mechanical and hydraulic engineering at the Royal Indian Engineering College at Cooper's Hill. Professor Unwin at present holds the honored position of Dean to the Central Technical College of the City and Guilds of London. He is also professor to the engineering department of the college, and to the long practical experience of Professor Unwin the institution is indebted for the complete organization of the work of this department.

In 1869 he brought out his work on "Wrought Iron Bridges and Roofs," and in 1877 his widely-known "Elements of Machine Design," familiar to every engineering student the world over, made its appearance. In writing this book, Professor Unwin aimed at supplying the need for a text-book for students. The work is at once clear, simple and written with the usual care which characterizes all the professor's work. Its primary object is to explain the principles available as guides in machine construction; to place the draughtsman in the best position to

make use of the facts coming under his notice in the workshop and drawing office, and to enable him to apply his experience in dealing with new materials for new forms of construction, and with novel conditions of force and speed. Probably the best mark of appreciation of the value of the book is furnished by the fact that it is now in the eleventh edition.

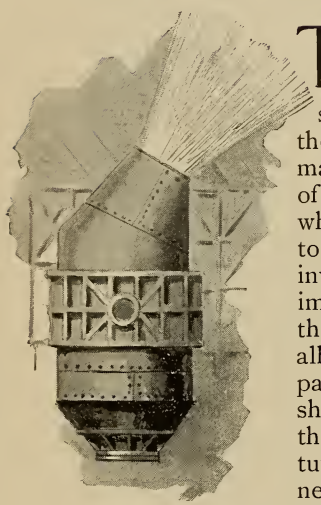
A still more important work, "The Testing of Materials of Construction," appeared in 1888, and was intended as a text-book for engineering laboratories. The work constitutes a standard treatise on the strength of materials used in construction, considered in connection with the instruments and methods by which the properties of materials are experimentally investigated. Professor Unwin maintains that, to properly understand the data on which the engineer relies in designing structures, it is necessary for him to have some knowledge of the methods by which they are obtained. He rightly contends that the introduction of new materials has necessitated a greater use for the testing machine, in order to estimate the proper constructional value of the materials. The intention of Professor Unwin in this work was to furnish the engineer with fuller means for understanding the methods of testing, believing, as he does, that experimental investigation is an essential part of engineering education. The book may be said to consist of three parts. The earlier portion of the work is devoted to a consideration of the mechanical properties of materials; the second part gives a description of the apparatus used in the engineering laboratory; and the last portion furnishes complete and trustworthy results of testing. In the preparation of "The Testing of Materials of Construction," Professor Unwin has given us not only his own great experience as a practical engineer, but also the best knowledge which his wide research has acquired. The greatest care was manifested by Professor Unwin in the collection of the more recent testing results. The rule observed in collection was that all the facts useful to observe about a material should have been obtained. In all cases where tables of results are given they have been carefully reduced to common units in order that they may be more easily understood and compared.

Professor Unwin has also shown himself active as an inventor. Among his inventions the following may be noted: A roller and mirror micrometer, by which instrument he endeavored, and with success, to avoid the trouble of taking two readings; and an autographic apparatus, very simple and accurate in principle. Another invention is that of an electric semi-autographic recording apparatus, an instrument by which a record may be effected easily and rapidly. More than 150 extensions may be taken in less than half an hour. The professor's inventions also include a screw extensometer, which obviates most of the difficulties of employing a micrometer screw; a cathetometer, an instrument for determining the difference of level of two points by a telescopic sight; a touch micrometer, of a simple and convenient character; and also an arrangement for measuring the compression of blocks.

Professor Unwin is a Bachelor of Science, a Fellow of the Royal Society, a member of the Institute of Civil Engineers, and of the Institution of Mechanical Engineers, an honorary associate of the Royal Institution of British Architects, and a member of the American Philosophical Society. He was also a member of the International Niagara Falls commission, appointed several years ago to examine into the various plans submitted for utilizing the power of Niagara Falls, and at the World's Fair at Chicago, last year, he acted as judge of some of the exhibits in water-wheels, pumps, air compressors, steam gauges and indicators, and machines for testing the strength of materials. While Professor Unwin's career has already been a busy one, he is, even now, only in the prime of life, with the promise of many years of activity yet before him.

# BENJAMIN HUNTSMAN, OF SHEFFIELD, THE INVENTOR OF CRUCIBLE STEEL.

*By R. A. Hadfield.*



THE present tribute to a great pioneer in the steel industry, with the accompanying remarks upon the town of Sheffield, England, which has remained to this day what his invention made it, an important centre of that industry, originally formed part of a paper, presented a short time ago before the American Institute of Mining Engineers, but has been variously modified so as to appeal to the interest of the general reader.

It was in the immediate neighborhood of Sheffield that the first successful process for the fusion of steel on a commercial scale saw the light. The late Dr. Percy, a leading authority in general metallurgy, said: "Formerly, so far as I am aware, steel was never melted and cast after its production; and in only one instance, viz., that of Wootz steel, was it ever molten during its production. Indeed, by the founding and casting of steel after its production its heterogeneousness is remedied, and ingots of the metal can be produced of perfectly uniform composition throughout, and for the practical solution of this important problem we are indebted to Benjamin Huntsman of Sheffield."

As a recent journal appropriately remarked, "Huntsman's patient efforts, at last rewarded with success, entitle him to an elevated niche among the heroes of industry. The invention of cast-steel was second in importance to no previous event in the world's history, unless it may have been the invention of printing."

Huntsman was born in 1704, his parents being natives of Holland, who came over and settled in England. He belonged to that sturdy religious persuasion, the Quaker body, which has done much for Great Britain, as it has for a large State in America, interested in the iron and steel manufacture. His character is shown by the fact that he would not allow any portrait to be taken of himself, and he refused an offer to be made a member of the Royal Society in 1750, when his fame had already begun to spread. The writer has had the pleasure of knowing both the great-grandson (recently deceased) of Benjamin Huntsman and also the present head of the business and fourth lineal descendant, Mr. Frank Huntsman. The latter successfully carries on the manufacture of the highest qualities of Huntsman's cast-steel, the name of which still stands in the first rank for quality, a striking example of continuous success in a business which is founded on the production of an article of the highest and best character. Not many of us can go back four generations to the origin of our business.

For several centuries Sheffield has been famous for its hardware productions, particularly in articles made of steel. Chaucer, about the end of the fourteenth century, spoke of Sheffield "thwytels" (from the Anglo-Saxon "thwyten," to cut or whittle), and, owing to the city's favorable surroundings, the trade grew to dimensions then considered large and important. It has

been described by some as a city founded upon seven hills, and although the writer has never yet been able to see this resemblance to the world's former metropolis, certainly there are plenty of hills and valleys in Sheffield. The latter naturally afforded a cheap and easy supply of water-power which, in times past, contributed much to the growth of the town. To this day its "grinding-wheels," as they are called, gradually dying out with the introduction of steam-power, dot the streamlets here and there. Many an American visitor would find it interesting to break his journey at the good old city, and see for himself these interesting reminiscences of the past. Black as it has been painted, and dirty as it may seem to one passing through in the cars, there is no city more picturesquely surrounded—"a black picture set in a golden frame," as Lord Palmerston said.

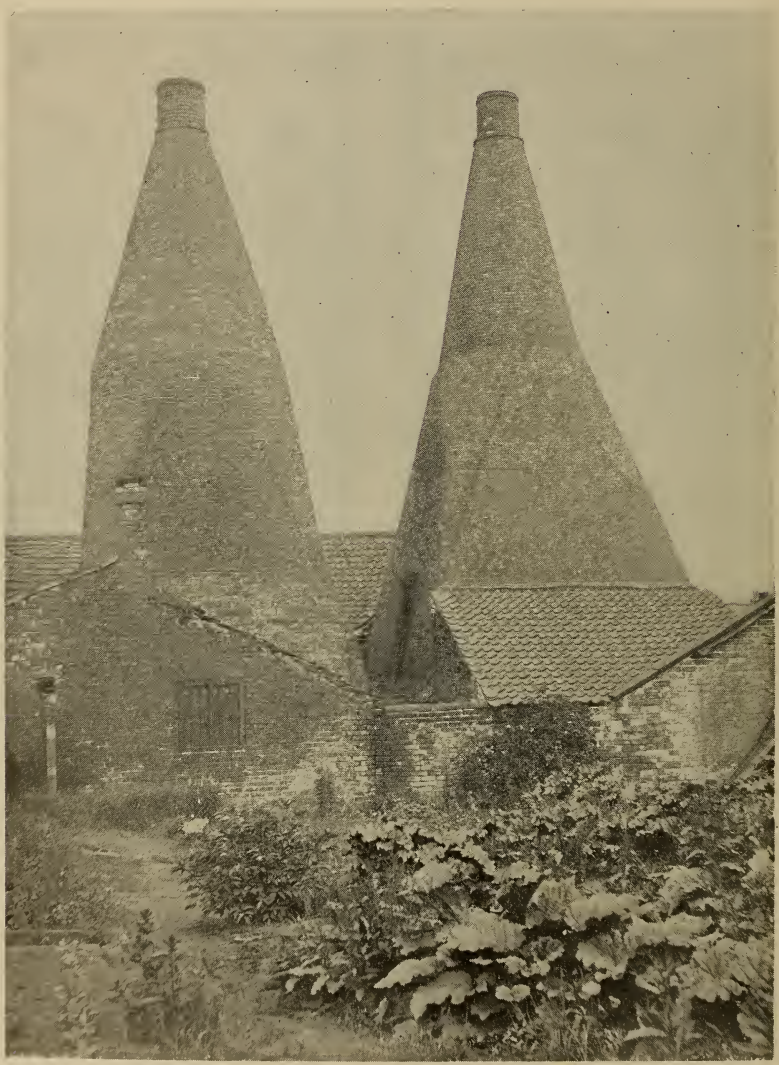
In the early part of Huntsman's life, about 1740, there was one great drawback in connection with the development of Sheffield. All the materials used had to be imported either from Sweden or Germany. Blister or cement-steel was imported from Germany and Sweden, or, in some cases, the material obtained was a raw puddled or natural steel. A considerable trade was also done with Newcastle-on-Tyne, where several cementation furnaces were worked, probably because the Swedish bar-iron more readily found its way there, owing to shipping facilities. Whether these latter furnaces existed when Huntsman first commenced his experiments is not very clear; but, in 1774, M. Jars, a French expert, who visited England that year, observed in his interesting Voyages Metallurgiques: "There are many manufacturers of iron and steel (cemented) at Newcastle-on-Tyne;" and it appears that a considerable quantity went to Sheffield. Huntsman, being a maker of watches and clocks, often experienced much inconvenience from the irregular quality of the imported blister-steel. For fine work of this class the utmost attention is essential to ensure uniformity of production. He was then setttled in Doncaster, and from reported proofs of his ingenuity it appears that he was already known as the "wise man" of the neighborhood. It is, therefore, not surprising to find that his active brain set to work to master the problem from which we to-day are reaping so great a benefit, namely, the production by fusion of cast-steel.

From a recent excellent paper by Mr. L. H. Holland, F. G. S., assistant superintendent of the geological survey of India, it would appear that Indian Wootz steel, usually found in conical ingots and made by the carburation of wrought-iron crucibles (so he states), has been made in India, and most probably for many centuries, especially in Trichinopoly. Nevertheless, Huntsman was very clearly the first to establish a fusion process on something like scientific lines, and to make it a practical and commercial success. Smiles, in his Industrial Biography, gives an interesting account of the discoverer, giving him the full credit after very careful investigations. Moreover, M. Le Play, professor of metallurgy in the School of Mines at Paris, after very carefully weighing all the evidence obtainable, stated that without doubt the credit of the invention belonged to Huntsman. Finally, a controversy was conducted in The London Times, some twenty-five years ago, and the discoverer, as we believe, was again fully vindicated.

Difficult as must have been the problem in the then crudely developed state of knowledge, having set his hand to the plough, Huntsman would not turn back. The crux of the difficulty lay in obtaining a fire-clay that would enable him to make a vessel or crucible in which the bar-iron or cement-steel could be made molten. At that time there was practically no knowledge as to the requisite chemical constituents of a fire-resisting material. There was uncertainty as to the character of the materials to be used in melting; melting appliances were imperfect, and there was difficulty in obtaining the most suitable fuels. These and other

obstacles would have appalled any but the stoutest heart. Mr. Frank Huntsman has informed the writer that evidences in their works were formerly abundant, and even quite recently some have been discovered, of the large number of experiments which had evidently been carried out in the early stage of the process. Buried salamanders are not unknown in the present history of metallurgy, and those found in the works of Huntsman are a proof that as now, so in the past, success usually comes after many trials.

Huntsman's first experiments were made at Doncaster, a town eighteen miles from Sheffield, to which city he removed about the year 1740. Here his further experimental work was carried out at Handsworth, a suburb of the town. Finally, he removed to Attercliffe, a manufacturing district forming



OLD HUNTSMAN FURNACES AT SHEFFIELD, ENGLAND.

part of the city, and his works are still in existence, considerably altered and enlarged, but situated in the street known to this day as "Huntsman's Row." Through the courtesy of Mr. Huntsman and the kindness of Prof. Arnold, whose skill as an amateur photographer is famous in Sheffield, the writer is able to present a view of part of the original works. These are of special historic interest, showing, without doubt, as they do, where crucible cast-steel was first produced on a practical and commercial scale. The cementation furnaces, as built and used by Benjamin Huntsman, differed in several respects from those of more modern construction. Within a few yards of the works is Benjamin Huntsman's house, where he lived until his death at the age of seventy-two, June 21, 1776. His remains lie in the family vault in Attercliffe cemetery. The steel employed in the work of Huntsman's clock, including that of the pendulum-rod, is believed to be the result of his first successful experiments.

The following excellent account is given of the methods originally practiced in Sheffield about 1764 by M. Gabriel Jars, in his Voyages Metallurgiques, edited by his brother, and published in 1774:—"Blister steel is rendered more perfect by the following operation: Ordinarily, the scrap and cuttings from articles of steel are used. Furnaces of fire clay (*fourneaux en terre*) are used, of similar design to those for brass castings. They are, however, much smaller, and receive the air by an underground passage. At the mouth, which is square, and at the surface of the ground, there is a hole through the wall, from which ascends the chimney stack. These furnaces contain only one large crucible, 9 to 10 inches high and 6 to 7 inches in diameter. The steel is put into the crucible with a flux, which is kept secret, and the crucible is placed upon a round brick, set upon the fire bars. Coal, which has been reduced to coke, is placed round the crucible, and the furnace is filled. Fire is then put to it, at the same time the upper opening of the furnace is entirely closed with a brick door surrounded by a circle of iron. The flame goes through the pipe into the chimney.

"The crucible is five hours in the furnace before the steel is perfectly melted. Several operations follow. Square or octagon molds, made in two pieces of cast-iron, are put the one against the other, and the steel is poured in at one extremity. I have seen ingots of this cast steel which resemble pig-iron. This steel is worked under the hammer, as is done with blister steel, but is heated less highly and with more precaution, because of its liability to break. The object of this operation is to make the steel so homogeneous that there may be no flaw, as perceived in that which comes from Germany, and this, it is said, can only be done by fusion. This steel is not extensively used; it is used only for purposes requiring a fine polish. Of it are made the best razors, some knives, the finest steel chains, some watch springs and small watchmakers' files."

The following passage, in another part of the same work, shows that attempts were being made in Newcastle, as early as 1765, to imitate Huntsman's methods:—"We were told also that in the southern part of England, that is, south of Newcastle, old files, or other old steel articles, or blister steel, are cut into pieces and put into a crucible with a flux, which is kept secret. It is said that each workman has his particular recipe. These crucibles are placed in a furnace to melt the steel. One person in particular has undertaken this process, two miles away from this town (Newcastle), but he has succeeded badly."

No doubt Huntsman's attention was at first confined to the supply of a material suitable for the purposes of his own immediate business, that is, clock springs; but it could not have been long before he saw the further important applications and uses that awaited the eventual development of this process, of which the fusion processes of Bessemer and Siemens are really the offspring. Huntsman exported his steel to France,

a trade still held by his firm. Sheffield cutlers became jealous of the advantages they thought his steel offered to foreign competitors, and it is said that they tried to influence the government of the day, but fortunately they failed in their attempt to restrain trade. That the process soon spread, is shown by a Sheffield directory, published by Gale & Martin in 1787, that is, about ten years after Huntsman's death. A list of steel manufacturers is there given, from which it appears that, in addition to Huntsman's firm, then trading under the name of Huntsman & Asline, as "steel refiners and melters," there were several other firms already engaged in the same business. The directory states that five firms were engaged in melting or refining, and about a dozen in the converting or cementation process.

That Sheffield can pre-eminently claim the title of "Steelopolis," not less from its modern development than from its long standing and traditional associations with the early developments of the metallurgical industry of iron and steel, is shown in an interesting manner by the same directory. We find that there were then some half-dozen manufacturers of adzes and hammers ; about 50 makers of edge tools ; not less than 40 engaged in file making; over 300 in pen, pocket and table knife manufacture ; at least 50 in razor making ; close upon 100 in scissors ; and some 60 or 70 in the manufacture of scythes, sickles and shears. Many of these were, no doubt, small workers rather than owners of large concerns ; but it will be seen that here was the centre for a considerable employment of steel. It was this, no doubt, that induced Huntsman to settle in Sheffield. The advantageous environments also proved to be of the greatest assistance in its rapid development. For example, its excellent supply of very pure water (also a source of cheap power) was believed by some to be of special quality and efficacy in the hardening of steel. In these days of investigation, many of the old ideas on these subjects have been exploded, and probably there is nothing in Sheffield water that cannot be obtained elsewhere, at least from water showing upon analysis the same chemical composition. Yet, not very long ago, a considerable quantity of Sheffield water was exported to America for hardening purposes.

It is curious that the ancients not only thought that the quality of the water was the most important factor in obtaining the right quality of steel, but that the Latin and Greek word for steel, *Chalybs*, was believed to have been given to a Spanish river (known to-day as the Cabe) in the Royaume de Galice, which flowed into the Vélézar, and the water of which had the reputation of conferring the best kind of hardening upon steel. M. Duhannel, a clever metallurgist of the last century, pointed out the foregoing in his Encyclopédie Méthodique de Chymie et Métallurgie, published in 1786. It is, of course, well known that the original "Chalybians, a people of iron workers," mentioned by Herodotus in the fifth century B. C., lived in Armenia, on the shores of the Black Sea. Sheffield's proximity to supplies of excellent stone or millstone grit, for which grinding and other stones, so largely used in the city's industries, are obtained, has been of considerable advantage. These grindstones have been in demand in many other countries. In the same way, the well-known Sheffield gannister and fire clay of excellent refractory quality appear to have been placed by nature just where they were likely to be wanted. In fact, Sir Henry Bessemer owed to this fact much of his early success. Sheffield gannister is still exported world wide.

Many of the names given in the directory of 1774, as connected with steel and hardware—for example, Spencer, Jessop, Peace, Wilkinson, Parkin, Turner, Rodgers, Tyzack, Sanderson, Hobson and others—are to-day still household words in the world's markets. In 1835 there were 56 converting furnaces and 534 melting holes ; in 1842 there were 97 converting furnaces and 777 melting holes ; in 1846 there were 105 converting furnaces and 974 melting holes. In 1848 the ratable value

was £272,000; in 1893, £1,250,000. The small beginnings of a century or more ago have expanded into a commerce of very large proportions. There are now over 250 different steel manufacturers and suppliers in the city; also nearly 1000 representing the cutlery, edge tool trades, and those engaged in other miscellaneous branches of manufacture, such as saws, files, etc. In times of ordinary trade, probably more than 1000 tons of the best quality of crucible cast steel are melted per week in Sheffield. Huntsman would indeed be startled to find his child grown into such a giant. America has developed the fusion of cast steel by gas melting furnaces and, with the kindly help of nature, in the wonderful application of natural gas. But without such aid, Sheffield now uses weekly some 14,000 clay crucibles in which to fuse its steel. The quality of this steel still stands unsurpassed in the markets of the world, and the main principle in the production of it are those brought into practice by Huntsman.

In connection with the subject the appended copy of a report made in 1792 is of considerable interest. It was prepared by Messrs. Fourness and Ashworth, engineers to their Royal Highnessess the Prince of Wales and Duke of Clarence, and bears the date of March 28, 1792:—

"In justice to Mr. Huntsman, who makes the best cast steel in this or, perhaps, any other country, we wish to present society at large with the following brief character of it, which, as persons who have for several years been in the practice of using it, we shall at all times be ready to confirm. We have made trial of different kinds of cast steel, but never met with any that would abide the same execution as Huntsman's.

"The efficient properties of Mr. Huntsman's cast steel are simply two, namely, extreme hardness, combined with great toughness and ductility. A point may be made of it that will cut glass, and at the same time endure arduous work, as a turning tool for any kind of metal, without undergoing those frequent repairs neccessary to tools made of other steel. It is calculated, also, to take the highest polish; therefore, for burnishing tools and plates to beat or roll any kind of metal to a fine surface upon, it possesses a decided superiority; and, as to dies, there is perhaps no steel that can be made into a face of equal hardness and durability. For buckles, buttons and other articles of the steel kind to which great superficial brilliancy is requisite, there is, we believe, not another fabric of steel so completely adequate. Indeed, as a hint to opticians, it is probable, this steel would admit of a polish sufficient for speculums; for mirrors it is particularly suitable. By a judicious workman a plate of this steel can be laid to and united firmly with any malleable iron or steel of even an ordinary kind.

"There are many smiths, within the compass of our knowledge, who have not been able to find out the real qualities of this steel, on account of having no previous instruction relative to the working of it. It has often been said, and amongst other incorrect statements it has been asserted that the Huntsman cast steel could not be united or welded to any other steel or iron; but the opinion is a mistaken one, because we can satisfactorily prove to any person that Mr. Huntsman's cast steel may be securely united or welded to any other steel or forged iron. To elucidate this fact is one part of the design of this testimonial.

"When smiths use cast steel they frequently imagine that it requires the same heat commonly given to other steel before it comes under the hammer; nay, some, indeed, think it is neccessary to give the same heat to it they would give to iron; whereas, if instead of this erroneous method Huntsman's cast steel were treated with care in the fire by the smith who works it, it might be brought into any required congenial state. It might, as already observed, be laid to any piece of wrought iron or steel. In fine, two pieces of the same steel, at a proper welding heat, will firmly unite under the hammer together. Steel of so fine

a texture as it is cannot bear excessive heat, since excessive heat undoubtedly destroys one of the two of its virtual properties, we mean its toughness.

"For the facing of anvils and hammers and the making of cold chisels no other steel we have been able to select can bear any competition with it. It may be tempered to any degree of hardness, and again brought down to any degree of mildness or ductility. Needles of all denominations, fish hooks of every kind, we are enabled to certify, may be much best relied on when made of this steel. Likewise (to be concise), edged tools of every description made of the same; screw taps and plates, drills and boring bits, points of tools for the digging of ores, coal, etc., most of which we have some acquaintance with, are more to be confided in than any other we have tried.

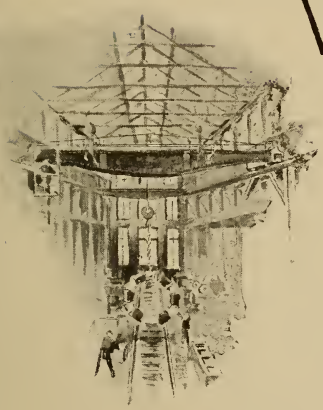
"It may not be unnecessary to observe (since the idea of interestedness generally produces bias) that we have no connection whatever with Mr. Huntsman, nor is it at all at his request or instance, we lay before the public this sketch of the qualities of his steel; for, we ingenuously believe, were the nature and properties of it better and more universally understood, mechanics in general would be benefited (since to all mechanical workmen safe and durable tools are of great importance), and the ingenuity and industry of the man who prepares it, by an extension of his sale, might be better rewarded. We are still the more induced to present to the public this impartial but imperfect character of Huntsman's steel, as we understand that during the course of more than thirty years of time devoted to the manufacturing of it he has so much neglected his own interest and credit, as never to give the public, through any general or circular medium, any account whatever of his steel. It was by accident that we learnt there was such steel, after being much put about to get such as would make tools to perform services which we could get no other steel to stand. All the orders we have since given Mr. Huntsman by pattern have been executed according to pattern.

"Springs of all sorts, scroll as well as others, may in general be depended on when made of this steel and suitably tempered; Huntsman, however, has suffered much by some manufacturers, or perhaps agents, unfairly making use of his stamp. Therefore, it would be prudent for those who wish to make trial of the genuine article, to purchase it from traders of known integrity, and such as do business with Huntsman himself, as there will probably always be some who would not scruple to deal surreptitiously in an article of high character.

"The whole of this information we offer to the public as friends to a man who, we think, ought in an advanced stage of life, as well for his own gratification as his family's prosperity and comfort, to be repaid by the increase of trade, for his expenditure of time and his sedulity in contributing to the convenience of the mechanical part of society."

# AN INTERESTING HYDRAULIC POWER PLANT.

*By Henry Harrison Suplee.*

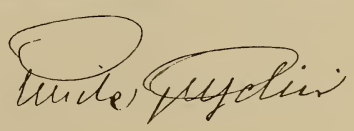


WHILE the engineering profession is awaiting the inauguration of the great work of the Cataract Construction Company at Niagara, it is none the less interesting to review and examine critically the successfully operating power plant at the Niagara Falls Paper Mill.

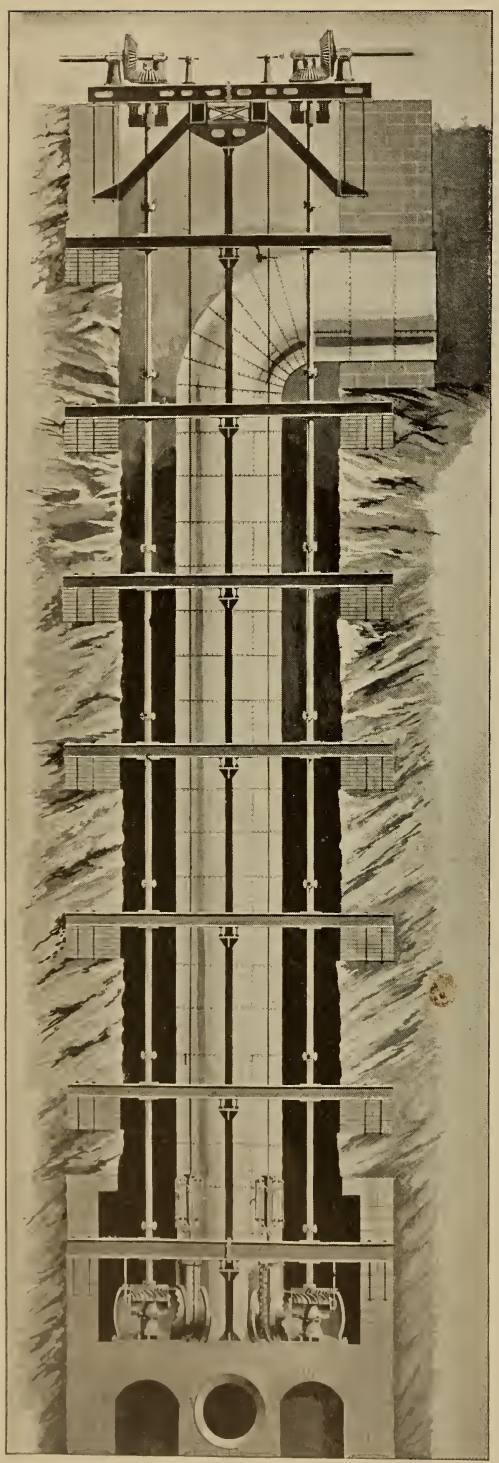
As is well known, the great tunnel nas been completed for many months, but the plant of the paper company is entirely independent of the larger plant, having only the use of the tunnel as a discharge in common with that of the Cataract Company. While the turbines used by the Cataract Company are made from foreign designs the paper company placed its work directly in the hands of Messrs. R. D. Wood & Co. of Philadelphia, and now that the three 1100 horse-power turbines have been running successfully, driven by the waters of Niagara for nine months, it is well worth while to give this advance guard of the exploitation army of the engineering attack on Niagara a full exposition.

The design and execution of this great installation of hydraulic power is due to the firm of R. D. Wood & Co., and was entrusted by them to their able engineer, Mr. Emile Geyelin, who, although French by birth, is American by adoption. A pupil of Jonval at Mulhouse, he has worthily demonstrated his faith in the turbines by his works, and the Geyelin-Jonval turbines at the Dupont powder mills at Wilmington, Del., at the Fairmount water-works at Philadelphia, at many other places, and last and greatest, at Niagara, form a record of which he and his firm may well be proud.

The great pressure at which the Niagara wheels were required to be operated, as well as the fact that the power was to be transmitted by shafting and gearing to the mill at the mouth of the shaft, made the problem one of great importance. Wheels have been operated under much greater heads,



but they were much smaller in size, while the problem of transmission alone was a most important one, as the speeds



THE TURBINE PLANT OF THE NIAGARA FALLS PAPER CO.

and forces were all close toward the upper limits of practice and theory. Mr. Geyelin soon perceived the importance of utilizing the pressure of the water to counterbalance the great weight of the shafting and gears, as well as that of the wheels themselves, and hence, instead of admitting the water between two wheels, he used inverted turbines, so proportioning the parts that the upward pressure of the water should largely carry the weight.

As an examination of the illustration on page 90 will show, each shaft is provided with a bearing directly under the gear wheel, this gearing being similar in construction to the thrust bearing of a screw propeller shaft, and on this bearing, and on the step beneath the turbine, the weight of the shaft and wheel rests when the turbine is not in motion. The detail shows clearly how the collar bearing is constructed and how it is free to centre itself with the shaft, and in connection with the general elevation drawing shows also how fully the bearing for the shaft and gears are braced and supported.

As the gates are opened the upward pressure of the water at once begins to relieve the downward pressure, due to the weight of the moving parts, and the proportions are such that the total weight is entirely counterbalanced when the gates are about two-thirds open. At full opening there is an upward pressure and at half opening a downward pressure, hence, at any time, it is only this positive or negative difference between the weights and the water pressure which comes upon the bearings. The manner in which this portion of the problem has been solved reflects great credit upon Mr. Geyelin, and the satisfactory manner in which the theoretical action is attained in practical operation shows how well the idea has been executed. When the pressure of the water is neutralized between two opposed turbines some other provision must be made for the weight of the shaft, while at the same time the lower turbine must operate under a greater head of water than the upper one by the amount of space between them. The above idea, however, has most

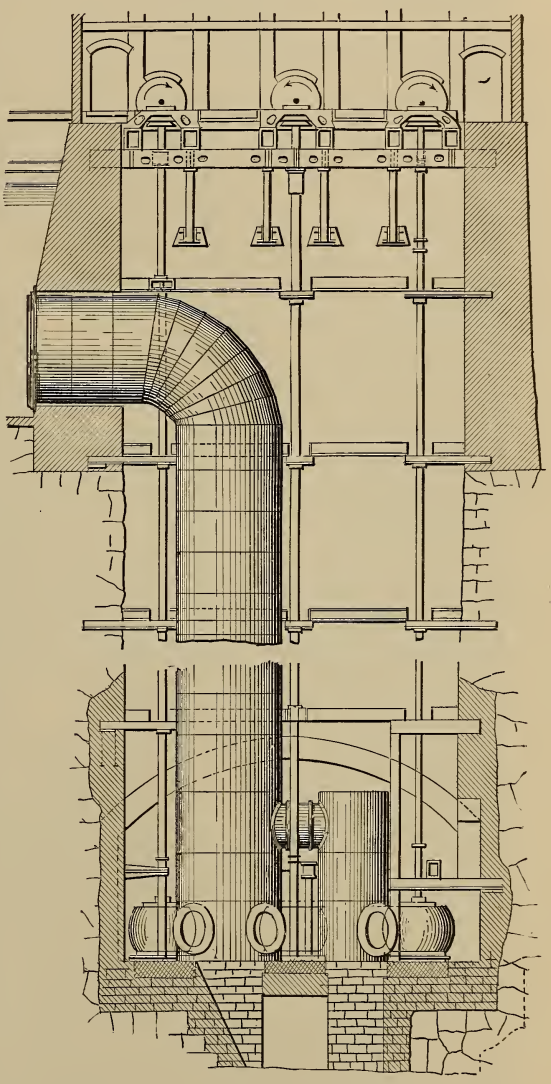
neatly disposed of two great difficulties by opposing them to each other and thus practically obtaining equilibrium.

The turbines themselves possess no peculiar features other than those due to the interest which their size and power naturally excites. They are the regular Jonval turbine with Geyelin's patent gates, and are so well known to the engineering profession as to be fully described by the illustrations.

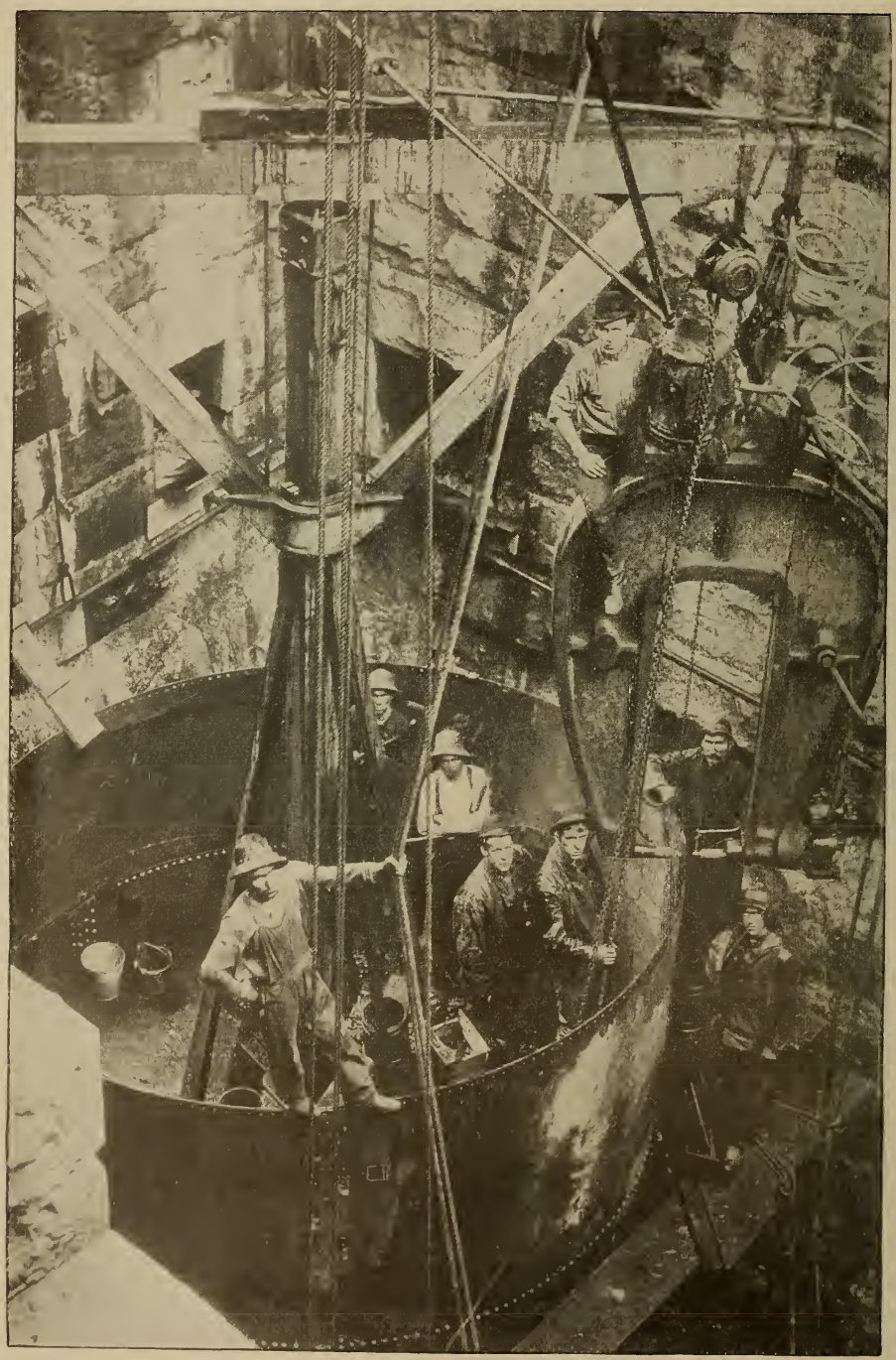
The movable wheels are four feet eight inches in diameter, with thirty buckets, and are of bronze, the speed being 260 revolutions per minute, each wheel developing, with full head, at this speed, 1100 horse-power. In order to reduce the velocity of the flow of water, the penstock was made quite large, being thirteen feet six inches in diameter, sufficient to supply four of the six turbines, although but three are now in operation. The illustrations show most effectively the construction of this portion of the work, and the reproduction from the photograph on the next page gives an excellent idea of the manner in which the hydraulic riveter, suspended from the end of a derrick arm, was enabled to reach every rivet hole in each rim of the geat shell quickly and accurately.

The metal of the great penstock is ⅞-inch thick, and the openings at the bottom, through which the water is distributed to the turbines, are so placed as to avoid unduly weakening the shell. This penstock is intended to supply four turbines, and an additional one of nine feet in diameter will be necessary when all six wheels are required. A short section of this 9-foot penstock is already in position, and is connected to the large penstock at a point above the other openings, as shown in the illustration above, thus providing for just one-half of the entire final installation, and making the addition of the remaining three wheels a simple matter at any future time. The opening for each wheel is 66 inches in diameter.

Each turbine was assumed to require 5186 cubic feet of water per minute, under a head of 145 feet, at an efficiency of eighty per cent., developing 1100 horse-power. As the present penstock is calculated to supply four turbines, the full capacity must be 20,744 cubic feet per minute, and with the diameter of thirteen feet six inches.



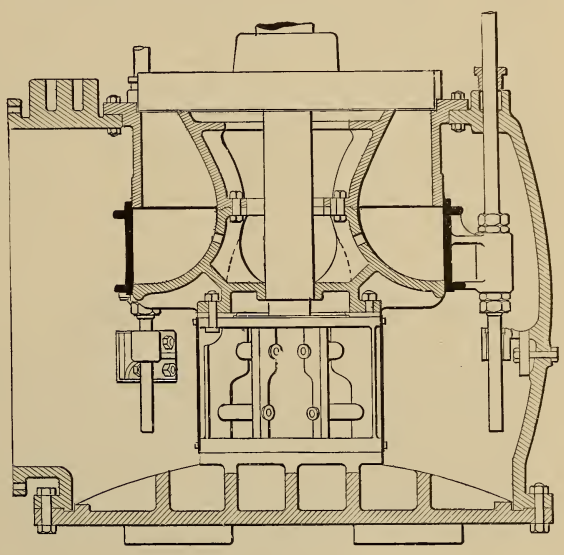
PARTIAL SECTION OF WHEEL PIT.



RIVETING UP THE PENSTOCK.

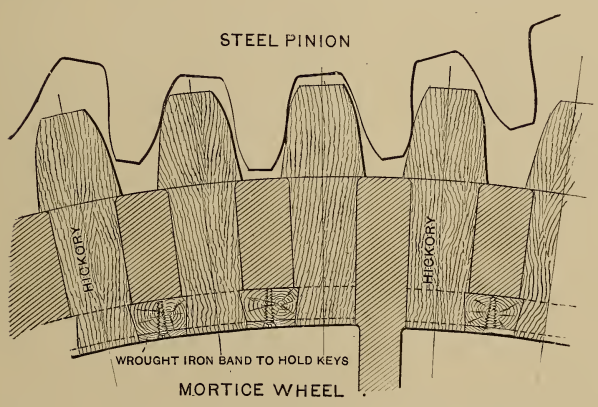
this requires a velocity of only 145 feet when supplying four wheels. The gates and apparatus for moving them are, as has already been said, of the Geyelin patent, and consist of heavy sleeves guided by rods and counterbalanced by a system of weights and levers with wire rope connections. Each sleeve weighs 2800 pounds, but is readily moved, owing to the counterbalancing. The pit, in which the wheels are placed, is rectangular in shape, measuring twenty-eight by forty-three feet and 172 feet in depth, blasted from the solid rock, the supporting beams being built into cavities cut in the walls, thus insuring a degree of stability most necessary with such massive and high-speed machinery.

Not the least interesting portion of the work is the transmission, dealing, as it does, with large powers and high speeds combined. In the case of the work of the cataract company, the fields of the electric generators are mounted directly upon the vertical shafts, but in the present instance gearing is necessary in order to deliver the power into the paper mill as required. Each turbine drives a vertical forged iron shaft, ten inches in diameter and 144 feet long. This diameter is in excess of the ordinary requirement for transmission of 1100 horse-power, but is intended to provide great stiffness, and thus keep the torsional deflection at a minimum.



SECTION OF THE GEYELIN-JONVAL TURBINE.

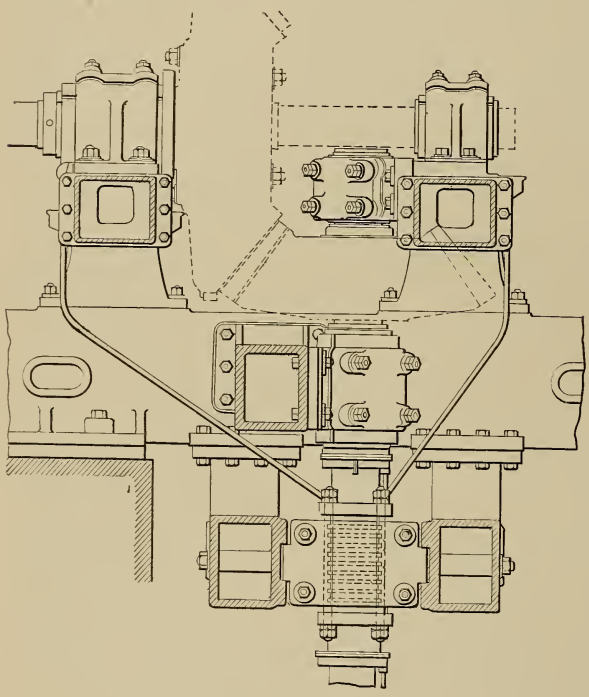
In order to transmit the power into the mill, each vertical shaft is geared by means of bevel wheels to a corresponding horizontal shaft, and the result is a set of gearing which, for speed and for the magnitude of power transmitted, is probably unsurpassed. As already stated, the turbine shafts make 260 revolutions per minute, and this speed is reduced by the gearing to 200 revolutions per minute on the horizontal shafts. Each set consists of a mortise bevel gear and steel bevel pinion, the mortise wheel being of 75.32 inch pitch diameter with forty-three teeth, and the pinion of 57.80 inch pitch diameter with thirty-three teeth, the pitch being five and one-half inches and the face twenty inches, each set weighing about 16,000 pounds. These gears run at the unparalleled velocity of 4000 feet per minute, while previous practice has been limited to from 2500 to 2800 feet




DETAILS OF THE TURBINE TRANSMISSION GEARS.

as the highest for bevel gears, or about 3500 for spur gears. Even these are considered extreme. While there is nothing especially novel in the construction of the gears themselves, they are excellent examples of correct proportion.

Some idea of the magnitude of the plant may be gathered from the fact that the pit contains about 1,400,000 pounds of material in the shape of girders, framing and wheels. The



ONE OF THE TURBINE SHAFT BEARINGS.

wheels have been in operation since January last, and the test of continuous service has proved both the correctness of the design and the complete manner in which the work has been executed. While the plant is exceeded in magnitude by the great installation of the cataract company, it is, with this exception, larger and more powerful, taken as a whole, than any other. In some respects it presents more points of interest for the general engineer than its greater neighbor, as the mechanism of transmission furnishes practical data of great value in other connections. It has been most fully demonstrated that bevel mortise gears can be safely operated at much greater velocities than has heretofore been considered practicable, while the correctness of the form and strength of teeth, as shown by the smoothness of action, confirms previous precedents far beyond the data from which they were deduced.

There is no doubt that much of the success of the transmission, both shafting and gearing, especially the latter, is due to the firmness with which all parts are held to their correct positions. Too often gearing is condemned as being noisy, or lacking in durability when the real fault lies in the fact that pitch lines do not coincide, or that angles in practice are by no means what they were laid out to be on the drawing board, and where correctness of position and alignment are not rigidly maintained it is of little use to form accurate tooth profiles or deduce close proportions. The "anvil" principle must be maintained in such work, if anywhere, and the example under consideration proves how much confidence may be placed in theoretical deductions if the assumed conditions are fully maintained.

The most original feature in this work, and one for which M. Geyelin is entitled to much credit, is the skillful manner in which two great difficulties have been compelled to neutralize each other. A vertical shaft is nearly always a troublesome thing to handle, even in the limited extent to which it is ordinarily found in mill engineering, and step bearings are not the easiest things in the world to manage. A mill shaft, however, is a plaything compared with these 10-inch pillars of forged iron, 144 feet long, revolving at

a rate of 260 revolutions a minute. Such a shaft, when laid horizontally in the tunnel of a steamship, with bearings at frequent intervals to carry the weight is one thing, but the same shaft on end at more than double the speed presents, indeed, a formidable problem to be solved. Again, a head of 145 feet of water means a pressure on the step which must be met with care even with small turbines, and when the wheels are nearly five feet in diameter such a head is without precedent. To turn the pressure of the water upward and make gravity acting upon the water balance gravity acting upon the shaft, was, indeed, a stroke of engineering genius.

## Current Topics.

BRIGHTON, in England, was recently the scene of a number of experiments with an armored train which recalls some of the earlier, though very practical, trials in the same line made about twelve years ago. England was then deep in the tangles of an Egyptian campaign, from which some very useful lessons were learnt in the art of war, not the least interesting among them being that a railroad train, fitted up more or less substantially as a moving fortress, was a comparatively new and valuable adjunct to both offensive and defensive operations in an enemy's country. One of the prominent English illustrated papers at the time published a realistic sketch of such a train, showing it to consist of a number of flat cars protected by light armor plates and sand bags. At the rear of the train was a Gatling gun ; the forward end carried one of the Nordenfeldt type. There were, in all, five cars, one of which was placed forward of the engine while the others were in the rear. Of these, one was equipped with a derrick. On the sides of the engine, spaces of about two feet above the drivers were protected by rows of sand bags, held in place upon rods. Compared with this early train, the one tried at Brighton several weeks ago is a rather more pretentions affair. It consists of one car, mounting a gun, and two cars intended for troops. The gun car has tall, steel bulwarks and the 40-pounder gun, which is mounted on a turntable, runs on inclined rails so as to reduce the recoil and cause the gun to run back to its place after having been discharged. There is also an hydrau-

lic buffer cylinder to serve as an additional check. Below the car, according to the available accounts, are telescopic girders which can be run out on either side or both sides at once, so that, by means of screw jacks at their ends, they form firm supports, taking the jar of concussion off the permanent way, while grapnels fore and aft take a firm grip of the rails and prevent the car from moving when in action. The outcome of the trials which were made by firing twelve rounds of solid shot, with full service charges, at a target buoyed at sea, 2200 yards away, is said to have been most promising, and it would, therefore, seem not unlikely that some future war will see the armored train playing an important and effective part.

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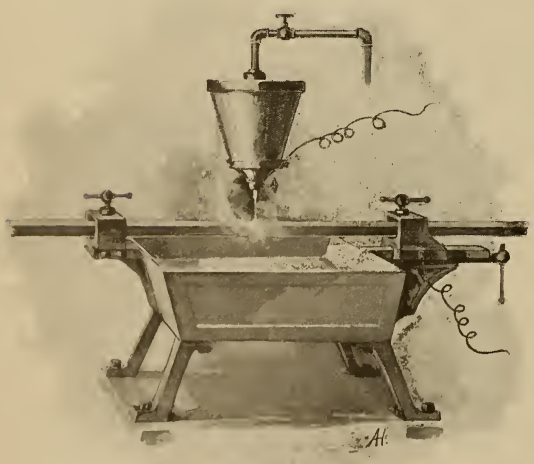
Most of the several electric welding methods that have thus far been exploited have consisted in sending an electric current through the parts to be united, though in several instances also



HEATING IRON RED HOT WITH A JET OF WATER.

use has been made of the heat of the electric arc. Still another method more recently appeared, and might, not inappropriately, be called an electrolytic one, since the heating effect depends primarily upon electrolytic action. Reference to one form of application of this method was made in these pages several months ago, and an apparatus was shown at the time which consisted of an ordinary water-pail containing an alkaline or acid solution, into which was placed a sheet of lead connected with the positive wire of an ordinary direct-current dynamo. The piece of metal to be heated was connected to the negative end of the dynamo, and upon being dipped into the solution, would at once be raised to a very high temperature. The principle of this peculiar phenomena, as then explained, was that when the negative electrode to which the metal was attached was placed in the solution, hydrogen gas was evolved by the electric current, just as in any other electrolytic bath. This hydrogen accumulated around the electrode, forming a gas envelope of high resistance and low conductivity, and the current which generated the gas, in passing to the negative electrode through this resisting medium, developed a very high temperature, under the influence of which the metal bar or rod became plastic and could be worked under the hammer.

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In another application of the same principle, where metal rods are to be welded together, end to end, substantially the arrangement shown in the annexed little sketch has been adopted. The rods to be united, it will be noticed, are held in clamps and can be forced together by hand. The current-carrying liquid is here simply allowed to flow over the welding point from a reservoir nozzle which is connected to the positive pole of the dynamo, and the metal bars to be welded are connected with the negative pole. The heating effect produced is the same as before. It does not depend on the conductivity of the metal to be welded, but on that of the surrounding hydrogen. The surface of the parts to be welded must, therefore, be taken into consideration, for if the surface be too large, the hydrogen evolved by a certain current may be-

come dissipated before the electrode will be sufficiently covered to produce the required temperature. Whether this method of electric welding is superior to that in which the current is passed directly through the metal remains to be seen. It would, however, appear that the principle involved allows of a large variety of applications.

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SPEED records, both of the vessels of the great Atlantic ferry and of the war ships of naval powers, have of late been so frequently broken that the task of keeping track of "the fastest steamer in the world" has become a somewhat confusing one. From the best available records just now, however, it would appear that for war vessels of appreciable size, ranging up into thousands of tons of displacement, 26½ miles an hour, equivalent to a little over 23 knots, is the highest rate that has yet been attained, and belongs to the latest of the completed United States cruisers, the Minneapolis, built by the Cramps, at Philadelphia. This figure was reached with triple screws, and an indicated horse-power equipment of about 21,000 for 7350 tons displacement, the dimensions of the ship being 412 feet length, 58 feet beam, and 22½ feet draught. Coming down to vessels of smaller size, however, speed performance is found considerably increased, as exemplified in the new twin-screw torpedo boat destroyer Daring, built for the British Navy by Thornycroft & Co. It is this boat for which the claim has been made of being the fastest war ship afloat, backed by the remarkable run of a little over 29 knots, or nearly 33½ miles an hour, recently made on the Thames. The mean of three runs was 28.656 knots, or about 32.9 miles an hour, and easily puts the vessel foremost in point of speed. The Daring is 185 feet long, 19 feet beam, and 13 feet deep, with a displacement of 228 tons.

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TRADITION ascribes the invention of the present method of making shot to a circumstance more interesting perhaps than strictly truthful. For years the shiny little lead pellets had been prepared by cutting up strips of sheet lead into little cubes which afterward had their corners rounded off by being agitated in species of tumbling barrels—a process obviously slow and imperfect. An old-time shot maker, so the tale has it, of bibulous disposition, after an evening at the village tavern with some boon companions, with ale befuddled brain drowsily sought his bed, and there dreamed strangely of walking along the highway in a pelting rain of lead, myriads of beautifully bright and round globules of the metal mercilessly pouring down upon him, and making him flee for shelter. Awakening, with the dream still fresh in mind, he determined at once to try for himself what effect would be produced on molten lead by dropping it from a great height, and hastily hied himself to the neighboring church tower, from which he poured a ladle full of liquid metal into a vessel of water below. Descending, he scooped up from the latter a handful of glistening shot, so round and true as he had never seen before, realizing most substantially the dream of the previous night.

DROPPING SHOT.

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FROM this early experiment sprang the shot tower of the present day, in which the molten lead, with a slight addition of arsenic for hardening purposes, is allowed to fall through a colander from a considerable height into a tank of water a hundred feet or

more below. The lead, in falling, forms itself into globules which are partially cooled in rushing through the air, and finally hardened by entering the water. The larger the size of shot, the more preliminary cooling will be required, so that large shot are allowed to fall through, say, 150 feet, and small shot through only about 100 feet. The colanders used are wrought-iron bowls perforated with smooth holes varying in size with the desired description of shot. The pellets from the water bath are subsequently dried on a hot metal plate, and the imperfect ones are sorted out by gently shaking the whole lot on a slightly inclined plate, when only the perfectly spherical ones roll down, the others remaining, being what are termed "lazy." Polishing in revolving cylinders, sorting as to size, and packing in bags for the market finish up the history of manufacture.

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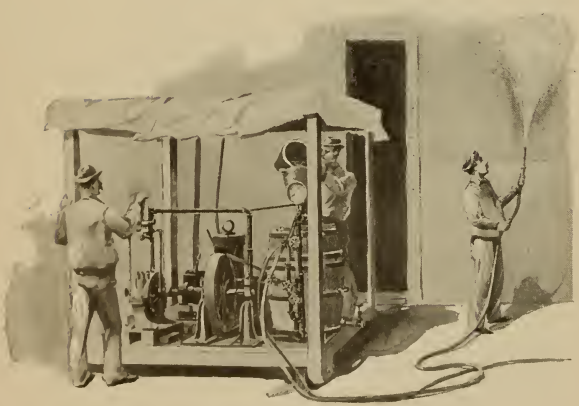
PAINTING without a brush, using, instead, a spraying nozzle and an ordinary garden hose, with compressed air as the spraying medium, was probably first practiced on a large scale in connection with the World's Fair buildings at Chicago, last year, where the vast extent of surface to be covered, and the short time available in which to do it put the conventional method by brush entirely out of question. After much study of the problem, Mr. F. D. Millet, the director of decoration, and his assistant, Mr. C. Y. Turner, had a painting machine rigged up which, in general design, is fairly depicted on this page, and in which the principle of the atomizer was most successfully applied to the novel purpose of spraying color upon walls and other surfaces. The compressed air was obtained from a small rotary engine which, with the electric motor driving it, and a paint and air reservoir, was mounted on a truck, so that the whole arrangement could be readily moved from one place to another. The paint and the kalsomine, which latter was extensively used in the Fair buildings, were poured into the reservoir after having properly mixed, and a jet of air at about twenty pounds pressure was forced through it from below, thus keeping the liquid in constant agitation, and preventing any deposit of sediment. From the top of the reservoir the air was led off by a pipe which descended at the side of the vessel and was joined below by the pipe carrying the paint or kalsomine, the resulting spray of color passing thence through a convenient length of garden hose to the point where it was wanted. The nozzle at the end of this hose consisted of a brass pipe, flattened out, so as to leave an opening about one-sixteenth of an inch wide, and an inch and a-half long. The paint, as will be readily gathered, was applied in much the same manner as one would sprinkle a lawn, and no skilled labor was necessary to properly work the apparatus. A very great saving of time and labor was, of course, the predominant advantage of the machine, against which the slight waste of paint, as compared with hand labor, was scarcely worth considering. On a more moderate scale substantially, the same method of painting by compressed air has been in use for a number of years by several railroad companies in the United States, shop walls and freight cars being treated by it with results which very clearly demonstrated the efficiency and economy of the system, the apparatus necessary costing less than it could sometimes save in a day.



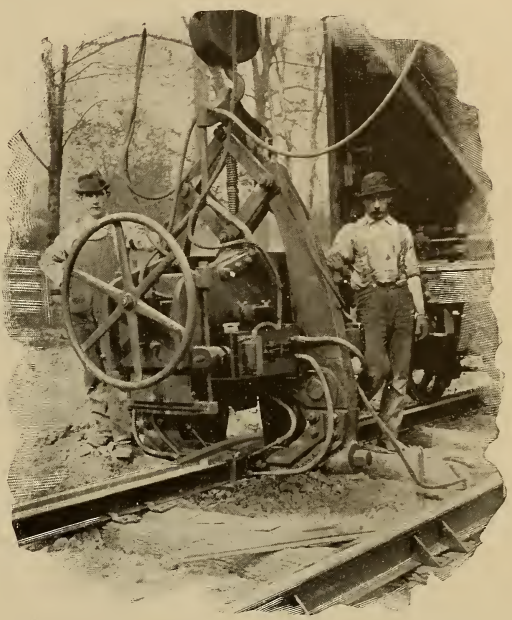
PAINTING WITH A GARDEN HOSE.

WHAT becomes of the expansion and contraction in the continuous rails, formed of ordinary rails electrically welded together at their joints, which are now used by a number of large electric street railroad companies in the United States? Many, no doubt, have asked themselves this question without being able to find a satisfactory answer. Still quite a comprehensive one has been given in a paper on the subject, prepared by Mr. A. J. Moxham, of Johnstown, Pa., and issued in pamphlet form by the Johnson Company of that place, for whom the experiments were made which led to the published results. Mr. Moxham's trial section of road was a little over 1100 feet long, the rails being imbedded in the roadbed as in current street railroad practice, and, while not welded together, they were bolted and clamped at the joints in such a way that the track was really continuous. Without following Mr. Moxham here through the various interesting details of his work, it must suffice to say that his experiments proved conclusively that the expansion and contraction, which were most certainly present with temperature variations,

AN ELECTRIC WELDING CAR.

were entirely taken care of by the surface friction of the road-bed in which the rails were partially buried.

FROM a temperature of 22 degrees Fahrenheit below the freezing point to



THE WELDING APPARATUS AT WORK.

a temperature of 89 degrees above, and with observations extending from March to August, there was absolutely no movement of the track out of place. Even at the ends was this true. The expansion in 1100 feet of rail, under the given range of temperature, would, according to Mr. Moxham, be equal to a little over 5 inches, and this would throw the rail about 14 feet out of line if it were held at the ends and permitted to bow in the centre. The expansion of a 30-foot rail would throw the latter about 6 inches out of line. To the query, "What has become of it," Mr. Moxham answers that, of course, it exists and would flow to the point of least resistance. In the case of a street rail, buried in the roadbed, it seems reasonable to believe that the expansion and contraction expend themselves

in minute enlargements and reductions of the sectional area of the rail. As to the effect upon the steel, it has been shown that the likely temperature variations would never produce stresses even approaching the elastic limit. On the face of it, therefore, there is nothing to prevent the abutting of rails, and this is but the prelude to an absolutely continuous track—one entirely without joints, with rails welded together up to such lengths as may hereafter be deemed best. Of course, the use of such a continuous rail would not be possible except under conditions like those ruling in street railroad practice, where the rails are imbedded and confined in the roadbed. It is the latter upon which the success of the practice wholly depends.

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In the practical application of the continuous track a number of precautions have suggested themselves. It must be remembered that a track so laid will be like a huge spring under tension or compression, safe and harmless when restrained by the roadbed, but ready to escape, like a shot from a cannon, if, while in this condition, the roadbed be removed. Mr. Moxham, therefore, would limit the length of a continuous rail to 500 or 1000 feet, and would have specially devised expansion joints at these intervals. The important features of the continuous rail, of course, are found in the elimination of the rail joint, which is always the weakest spot in the whole structure, and, with it, in the more nearly perfect establishment of an ideal metallic circuit for eletrically operated roads.

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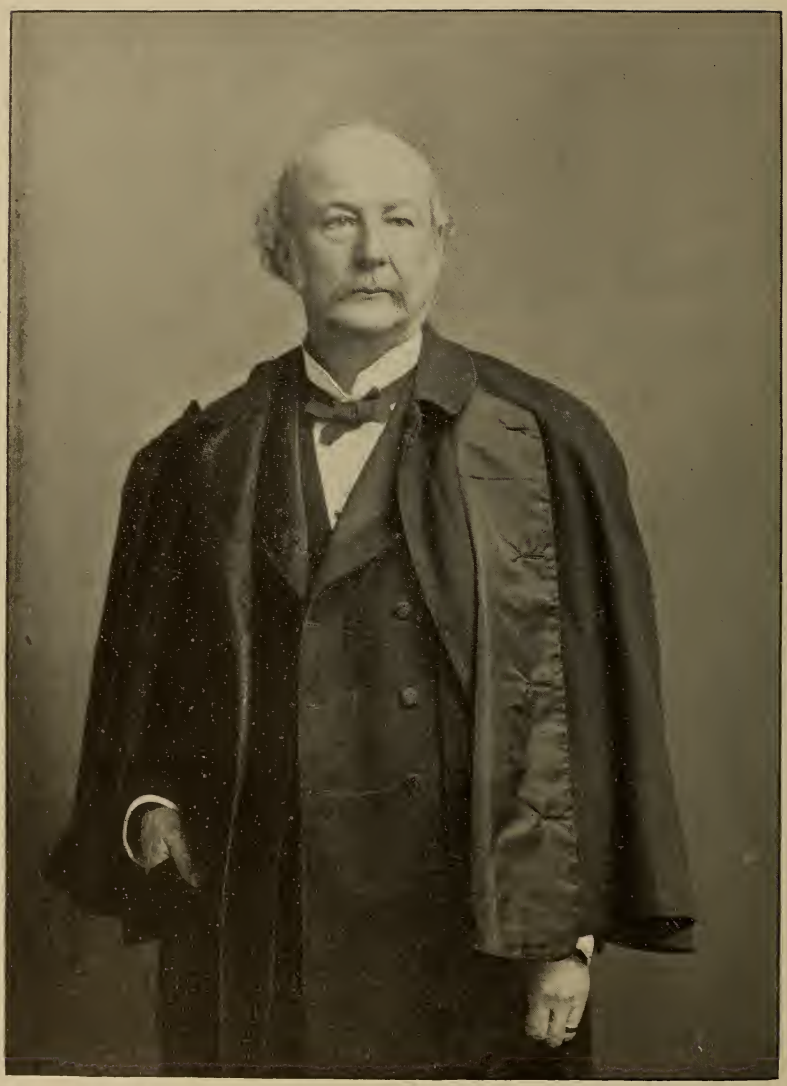
After what has just been said of continuous rails and, incidentally, of electrically welded joints, it will naturally be of interest to refer somewhat more specifically to the manner in which the welding is accomplished. One of the illustrations on the preceeding page shows a railroad welding car complete, furnished to the Johnson Company by the Thomson Electric Welding Company of Lynn, Mass,, and the other represents more in detail what might be termed the business end of the car at work. In carrying out the operation, the ends of the rails to be joined are first brought solidly together by driving a wedge in the joint ahead. The welding car is then run over the joint and the welding takes place at the rear of the car, so that it is not necessary to run over a hot joint. By means of an emery wheel, driven by a small electric motor taking current from the line wire, the webs of the rails are polished, steel lugs, or bridge pieces, are then placed on each side, and heavy copper contact pieces between which the welding is done are screwed down upon them. An alternating current, obtained from a rotary transformer fed from the main line, is then passed between the contacts, raising the joining lugs to a welding heat. Then, by turning the large hand wheel, seen in the second illustration, the toggle joint arrangement, which is clearly shown, is brought into operation, forcing the now plastic lugs up against the rails and partly into what space may be between the rail ends. This is virtually all that there is to the process, except that the rail tread and flanges are subsequently smoothed up by hammering, before the joint has had an opportunity to cool and after the apparatus has been unclamped and moved on to the next joint. The machine, as shown, is hung from a crane, so that it may be readily swung from one rail to the other. The copper contact pieces are hollow, and are provided with water circulation to keep them cool. The toggle joint arrangement of the clamps enables a great pressure to be brought to bear upon the weld and helps to insure a perfect union. From fifteen to twenty minutes suffice to complete a joint.



Yours faithfully
E. Windsor Richards

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# CASSIER'S MAGAZINE.

VOL. VII. DECEMBER, 1894. No. 2.

## THE NEW AMERICAN NAVY.

*By Lewis Nixon, Naval Constructor at Cramp's Shipyard.*

THE entire absence of effective vessels from the United States Navy list began to attract public attention about the beginning of the Forty-fifth United States Congress in 1879, and the naval committees of this Congress and of the Forty-sixth Congress investigated the condition of both American and foreign navies, and reported in favor of new men-of-war. Previous to the assembling of the Forty-seventh Congress, the Hon. W. H. Hunt, Secretary of the United States Navy, organized a board with instructions to report upon the number of vessels needed, together with their class, size, displacement, armament, machinery, equipment and cost. This report was submitted to the Secretary of the Navy, late in 1881. The report was a most favorable one, not only from its recommendations, but on account of the information which it contained relative to the types and numbers of vessels owned by other nations.

None of the vessels recommended were built, but the report was used as a basis of operations by the Forty-seventh Congress, which, in an act approved

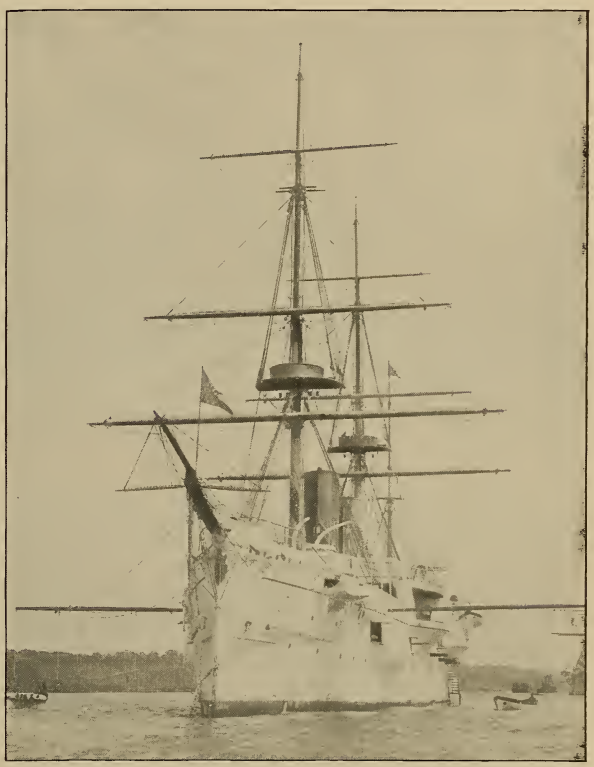
THE BRITISH TORPEDO-BOAT DESTROYER HAVOCK.

U. S. CRUISERS BOSTON AND ATLANTA.

August 5, 1882, provided for the completion of the double-turreted monitors, and authorized the construction of a 6000-ton protected cruiser. The Hon. William E. Chandler, then Secretary of the Navy, found the authorization for the cruiser so vague that he would not begin it. The second session of this Congress, however, passed a definite bill, the act of March 2, 1883, authorizing the construction of four ships and appropriating $1,300,000 to begin them. Secretary Chandler had plans all prepared and, on July 2, 1883, opened the bids for these vessels, which are now known in the service as the Chicago, Boston, Atlanta and Dolphin. The contracts for all four cruisers were

obtained by the late John Roach, together with the contract for building the machinery of the monitor Puritan. The contract for building the engines of the monitor Terror was awarded to William Cramp & Sons, and that for building the engines of the monitor Amphitrite, to the Harlan & Hollingsworth Company. Thus began the new United States Navy. The new vessels were to be commerce destroyers, but, at the same time, the feeling that the country should have armored vessels as well, was carried out by provisions for finishing the double-turreted monitors which had been commenced in 1874. Even those with a better understanding of the necessity for heavily armored battleships were well pleased with this beginning, as the resources of the country were not such as would enable American builders to turn out the armor or guns for heavier vessels, while the rapid disappearance of the wooden fleet made it absolutely necessary to build some new vessels to take the places of the old ones.

Legislation for the new navy assumed a national complexion. The act approved March 3, 1885, authorized four additional vessels, appropriating $1,895,000 for beginning their construction. This act was of vast importance to the new navy. Before that time, money for new ships was voted as a special act, but in this bill it was made a part of the regular naval appropriation bill. The fate of a special bill is always in doubt, but the regular bills have a right of way, and so the plea for new ships is sure of a hearing. This practice has been followed ever since. But this bill went further in the way of securing good ships, by providing that repairs should not be made upon any existing wooden vessel when the cost of such repairs should exceed twenty per cent. upon the whole cost of such vessel when entirely new. This brought about a rapid retirement of the obsolete wooden fleet, emphasized the need of building new vessels to take their places, and saved a great deal of money annually spent in rehabilitating the wooden hulks. The provisions of a law seem hard when they bring about the end of ships like the noble old Hartford, but even from a sentimental standpoint it would seem better to perpetuate such names as, for example, Hartford and Kearsarge in modern ships as capable of upholding the honor of their country in combat with the battleships of other nations as were their namesakes in their day.



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U. S. CRUISER CHICAGO.

The vessels built under this act were the Newark, Yorktown, Petrel and Charleston. Bidders were permitted,

in this case, to submit plans of their own or bid upon the plans of the Navy Department. Messrs. William Cramp & Sons, of Philadelphia, took advantage of this opportunity to bid on vessels with triple-expansion engines instead of compound, as called for by the Navy Department's designs. The Newark and Yorktown, built by the Cramp Company, accordingly have triple-expansion engines. Since that time all large vessels built for the United States Navy have been provided with engines of this type.

The Newark and Yorktown were the first contracted for by the Secretary of the Navy, Mr. Wm. C. Whitney, and in the contracts he inaugurated the system of premiums and penalties, every indicated horse-power above a certain fixed figure entitling the builder to a certain sum, while for failure to attain this figure a penalty was exacted. Experienced ship builders were enabled to place their bids low under this system, relying upon their skill and thorough workmanship to get their profits out of the premium. Generally speaking, the vessels so far mentioned were protected cruisers and gunboats. Reference can best be made to the vessels under the following general heads :

Protected cruisers, or vessels having the machinery and ammunition rooms covered by a thick curved steel deck, dipping below the water line at its edges ; the guns and their crews exposed or only protected by light shields ; gunboats, or small cruisers without even a heavy deck to protect their machinery ; battleships, or vessels which can meet at sea ships carrying the heaviest armor and guns ; harbor defense vessels, or vessels so low in the water that, unless the sea be perfectly smooth, they cannot act efficiently, except in bays and land-locked harbors (the monitor is in this class) ; armored cruisers, or vessels having side armor in addition to the protective deck, and whose guns are protected by barbettes or turrets, the armor being much thinner than that used on a battleship.

The first American protected cruisers

U. S. GUNBOAT YORKTOWN.

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U. S. MONITOR MIANTONOMOH.

had very light protective decks, but they had enormous batteries. The Chicago, on 4500 tons displacement (the word displacement being a measure of size, and when expressed in tons being equivalent to the actual weight of the vessel), carries a battery of four 8-inch rifles, ten 6-inch rifles and two 5-inch rifles, while the Atlanta and Boston have more fighting power in their 3000 tons of displacement than many 4000-ton vessels in other navies. The 8-inch gun fires a 250-pound shell and the 6-inch gun, a 100-pound shell. The 6-inch gun was a favorite for a long time. Even the gunboats, like the Petrel and Yorktown, carried four and six 6-inch guns respectively. These guns are, of course, breech loading and are loaded by first putting in the shell and then the bag of powder behind it. Of late years, however, larger and larger guns have been made rapid-firing, that is, with the powder and shell all in one piece like a pistol cartridge, and breech opening and closing devices such that the loading can be done almost in one motion. The later American gunboats have, therefore, on account of the greater efficiency of the rapid-fire service, been supplied with 4-inch and 5-inch rapid-fire guns. The protected cruisers have, as a rule, a main battery made up of 6-inch rifles, in some cases having 8-inch, 5-inch and 4-inch guns also. The main advance over the Chicago has been in speed and the thickness of the protective deck, together with armored sponsons for the guns.

In 1886 provision was made for two sea-going armored vessels, and for the armament of the double turreted monitors, together with a protected cruiser, one first-class torpedo boat and a dynamite cruiser. With such a programme the American government found itself confronted by the fact that no plants existed in the country capable of making heavy armor. The only heavy armor so far used was for the turrets of the monitor Miantonomoh, and this had been bought in England. The tubes and jackets of all guns over 6-inch calibre, and the shafts for the Baltimore,

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THE PROTECTED CRUISER BALTIMORE.

Charleston, Yorktown and Vesuvius, were imported. Authority was, therefore, given to the Secretary of the Navy to take such steps as might be necessary to procure armor of domestic manufacture, and he was also authorized to expend part of the appropriation to make or purchase such tools and machinery as might be required in the manufacture of guns and mounts for the vessels of the new navy. As an outcome of this it was decided to equip the navy yard at Washington as a national gun foundry. Then certain contract inducements were held out to, and accepted by, the Bethlehem Iron Company, at Bethlehem, Pa., and this company erected a forging plant capable of supplying whatever material might be needed for armor, guns and shafting.

The sea-going armored ships authorized in 1886 are now nearing completion. One, the Texas, from designs furnished from England in competition, is building at the Norfolk navy yard and will be a powerful and useful second-class battleship. The other, the Maine, an improvement upon the Brazilian ar-

THE TORPEDO BOAT CUSHING.

mored cruiser Riachuelo, is building at the New York navy yard. The protected cruiser was built by the Cramps and named the Baltimore. She is one of the most efficient vessels of her type in the world and has rendered good service in many waters. The dynamite cruiser was built on plans of hull and machinery by the Cramps, and was armed with three pneumatic dynamite guns. This vessel was designed to land, with

A RELIC—THE CONSTELLATION.

safety and accuracy, large charges of high explosives at distances of over a thousand yards. While the fuse for exploding the dynamite, which at first gave trouble, has been perfected, there is still some talk of converting the ship into a torpedo-boat chaser. As to the wisdom of such conversion, after the excellent results attained by the United States Army Board, opinions differ. The first-class torpedo boat was built by Herreshoff, and was named the Cushing. She was up to the same high standard which characterizes all the vessels of the new navy and is one of the best vessels of her date in the world. A second boat, named Ericsson, is now practically completed, having been built at Dubuque, Ia.

In the spring of 1887, four additional vessels were authorized. These were the 19-knot protected cruisers Philadelphia and San Francisco, and the gunboats Bennington and Concord. The Philadelphia is a modified Baltimore, with engines by Cramp & Sons, and the San Francisco is a modified Newark, with increased power. The Bennington and Concord are duplicates of the Yorktown. It was provided at the same time that $2,000,000 might be spent on floating batteries, rams or other naval structures. This money was subsequently used to build the Monterey, a powerful and efficient monitor built under contract by the Union Iron Works of San Francisco. Fifty thousand dollars were appropriated for the purchase and test of torpedoes. This sum has

THE DYNAMITE CRUISER VESUVIUS.

been so well utilized by the Bureau of Ordnance that the government is now able to install complete batteries of torpedoes on all the new vessels.

In 1888 the building of the New York and Olympia, the Raleigh and Cincinnati, the Detroit, Montgomery and Marblehead, and the practice ship Bancroft was authorized. In the New York, built by the Cramps, we have the ideal armored cruiser. She is a vessel 380 feet long, sixty-four feet wide, with a normal draft of twenty-four feet, and has developed a sea speed of twenty-one knots an hour. The protective deck is six inches thick in the wake of the engines and boilers, reinforced by side armor four inches thick. The main battery consists of six 8-inch rifles, two forward and two aft in armored turrets, and one on each broadside in armored barbettes with thick protecting shields. On the gun deck there are twelve 4-inch rapid-fire rifles in armored sponsons. There are also eight 6-pounders, several 1-pounders and six torpedo guns for firing torpedoes. The ship has great coal-carrying capacity, and, having two engines on each shaft, one of which can be uncoupled for economical steaming, she can keep at sea for a great length of time.

In this and subsequent vessels the "raft-body" idea has been utilized, that is, a cofferdam has been worked along on each side of the ship above and below the water line, which has been packed with obturating cellulose. Shell may pass through this, but it swells up and closes the shot holes so that the water line is left intact. The shells are kept from the vitals by the protective deck, while the always intact raft of cellulose along the sides keeps out the water. Cellulose is now manufactured in the United States, and the domestication of this industry along with that of armor and gun-making can

be placed to the credit of the new navy.

The Olympia, built at the Union Iron Works, is in some senses a smaller New York. She has no side armor, but her 8-inch guns are in turrets and she has a heavy protective deck and the cellulose raft body. The Raleigh and the Cincinnati were 3000-ton protected cruisers with 10,000 horse-power engines. As no bids were received within the limits of the appropriation, one of the vessels was built at the New York and the other at the Norfolk Navy Yard. They are now in commission.

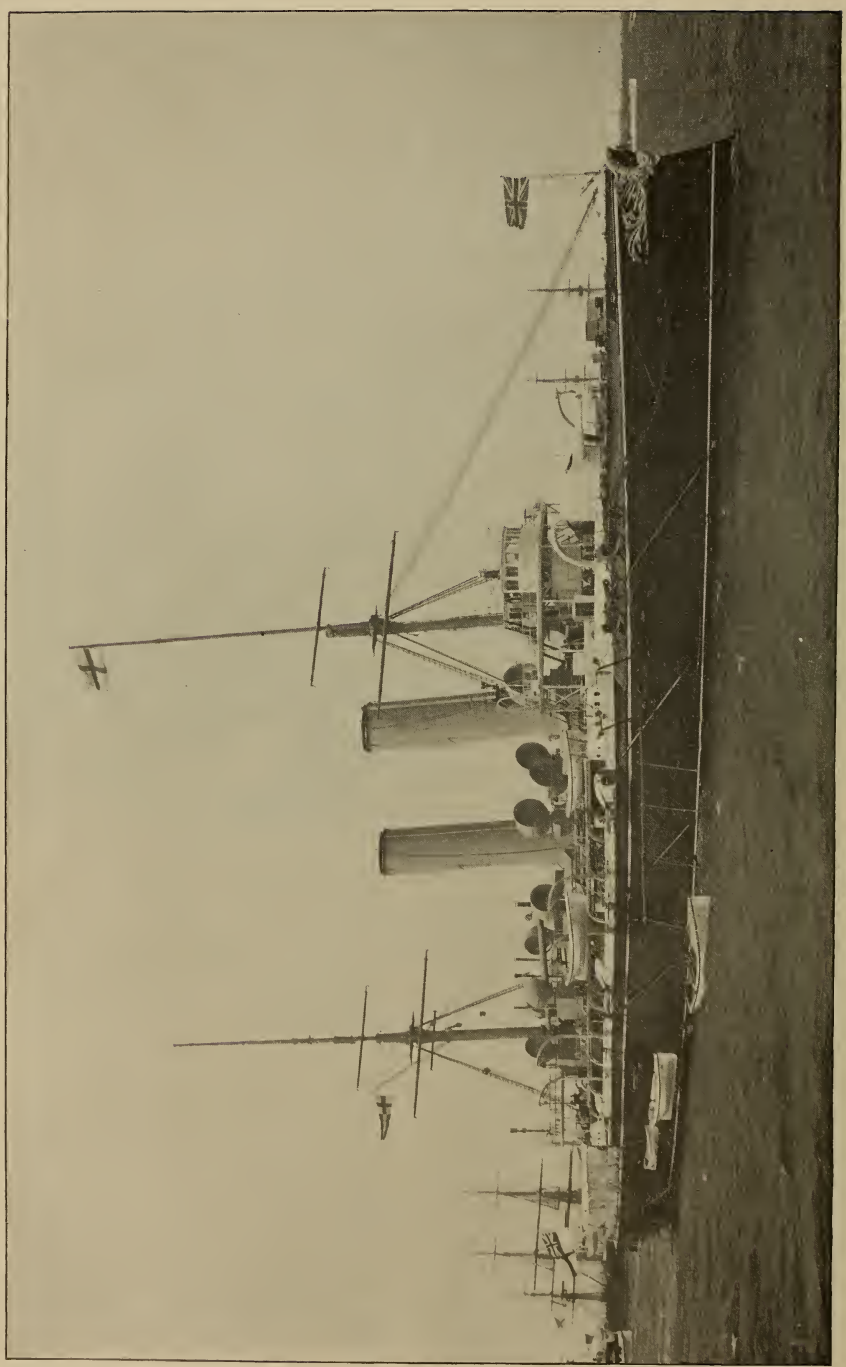
The Marblehead, Montgomery and Detroit are gunboats a little larger than the Yorktown but of the same general type, except that their larger guns are protected by armored sponsons. The Marblehead was built by Mr. Harrison Loring, at Boston. The Montgomery and Detroit were built at the Columbian Iron Works at Baltimore. The bidding on these vessels affords an interesting view of the premium question. When bids were first asked for, eighteen knots speed were required. None of the bids were within the limit of the appropriation. The speed requirement was then reduced to seventeen knots, with a bonus of $25,000 per quarter knot for speeds above seventeen knots. The bids then dropped approximately the $100,000 that the reduction of the knot represented, so that, in the long run, about the same amount was paid for these vessels, since they exceeded eighteen knots on trial. The practice vessel Bancroft was built by the Samuel Moore & Sons Company of Elizabeth, N. J. She is well built, and admirably adapted to the purposes for which she was designed, and realized a speed above that contracted for, greater proportionally than any of the vessels of the new navy.

Up to this time the United States had been adding smaller types of vessels that, class for class, were relatively superior to those of other powers, but by a later provision, the Secretary of the Navy was enabled to begin the construction of first-class battleships, and to forge ahead of other nations in the protected cruiser class. This law authorized the Indiana class of battleships and the Columbia class of protected cruisers.

Two small gun boats, the Machias and Castine, were authorized, and were completed at the Bath Iron Works, Maine. These are exceedingly useful little vessels and have shown great speed. The battery, as determined on, was a little too heavy for the boats, and the alternative of bringing the vessels up to their battery instead of reducing the battery down to the vessel was accepted by the Department. They were accordingly lengthened, and can now carry the guns that were considered necessary on such vessels. A harbor defense ram, on the plans of Rear Admiral Daniel Ammen, U. S. N., is also building at the Bath Iron Works, and is rapidly nearing completion. With the realization of the designer's claims this will be of great service in defending harbors in case of war.

A BOW VIEW OF THE VESUVIUS.

The appearance of a large fleet of American commerce destroyers, like



THE BRITISH CRUISER BLAKE.

FROM A PHOTOGRAPH BY WILLIAM H. RAU

the Baltimore, Newark and San Francisco, was met by the English Blake and Blenheim, protected cruisers of 9000 tons, the object of which in war would have been to destroy American commerce destroyers. This challenge was met by the New York, an armored cruiser that was faster and could outfight her, and which, with as thick a deck as the Blake, was able to carry

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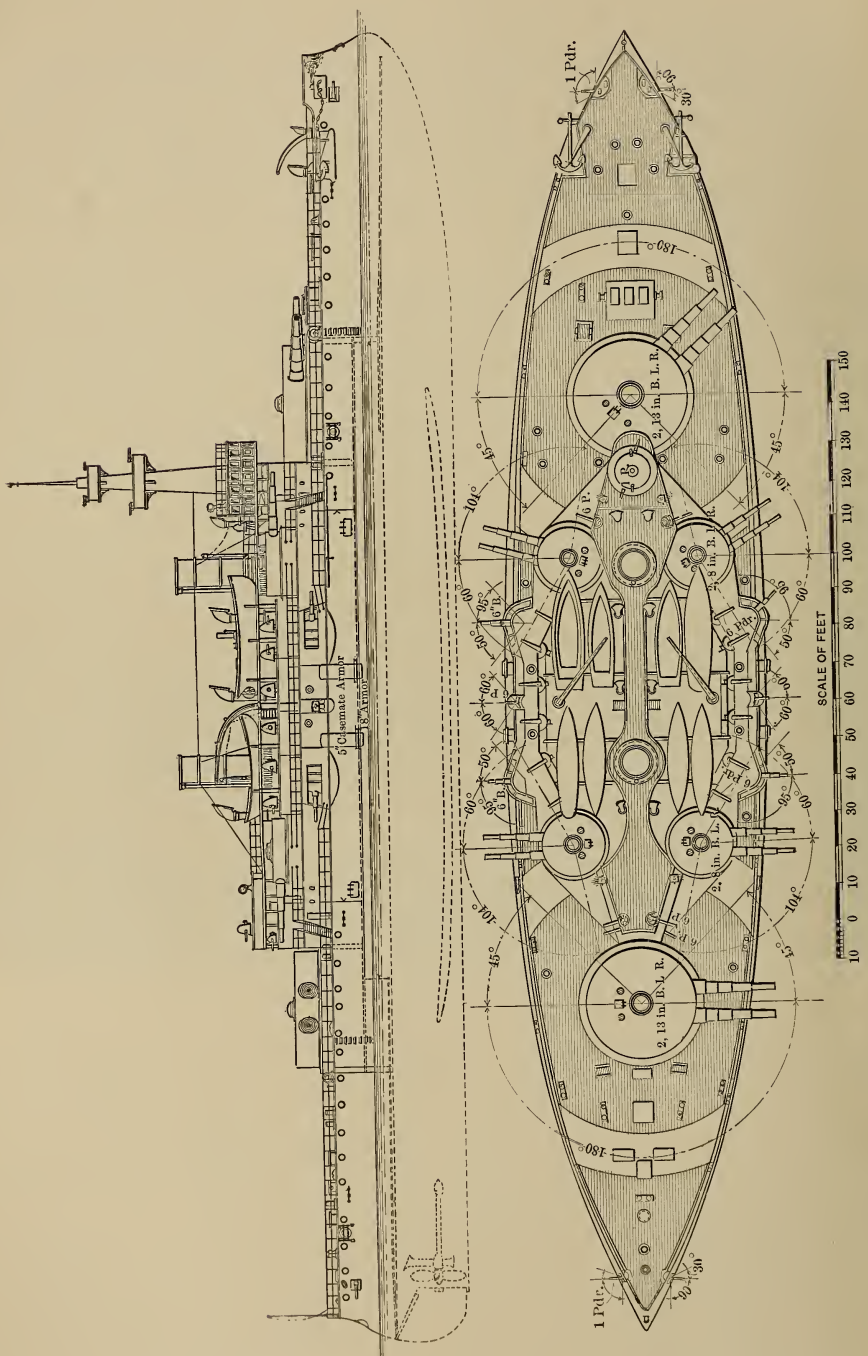
ARMORED U. S. CRUISER NEW YORK.

side armor and a cellulose belt—all on a thousand tons less displacement.

About this time the English Government began the construction of eight enormous battleships of 14,000 tons displacement, to offset which, the United States authorized the construction of three battleships which according to the law were to carry the heaviest armor and most powerful ordnance. These vessels, the Indiana and Massachusetts, now being built by the Messrs. Cramp, and the Oregon, by the Union Iron Works, are nearing completion. By direct comparison with the latest and best type of battleship then designed, as embodied in the English 14,000-ton vessels, they will be seen to have carried out the law on 10,300 tons displacement. These vessels, after a careful study of the battleships of other nations and the conditions defined by the United States coast line and probable policy of the United States as a nation, were designed with a view of meeting in battle vessels carrying the heaviest guns and armor. They are of great fighting power, united with adequate protection, and able to take the sea in all weathers, with draught suited to work in shallow harbors.

The hull is protected by a belt of heavy Harveyized nickel-steel armor, seven and one-half feet deep, turned in forward and aft to sweep around the bases of the armored redoubts. The belt is three feet above and four and one-half feet below the water line. Forward and abaft this belt are three-

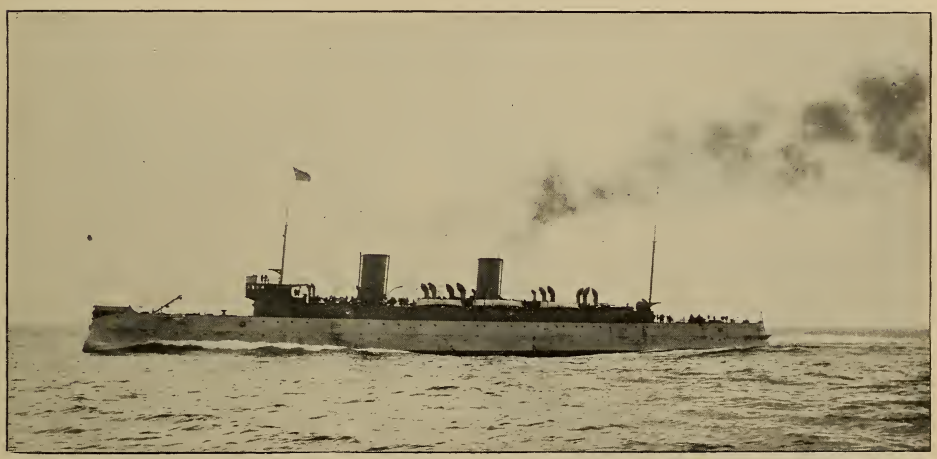



U. S. BATTLE SHIPS OF THE INDIANA CLASS.

inch nickel-steel decks, sloping at the sides to four and one-half feet below the water. There is also an armored deck over the belt. Coal bunkers are worked over the belt deck, and belts of cellulose, six feet thick, are worked on the slopes of the armor deck forward and aft. Above the belt armor, and extending from redoubt to redoubt, the side is protected by five inches of armor. The vessel is cut up forward to add to the manœuvreing power and enable her to readily disengage herself from an enemy after ramming.

Rising from the armored citadel, made by the 18-inch belt, are armored redoubts, seventeen inches thick, extending through the main deck three and one-half feet, giving an armored freeboard of fifteen feet two inches. These redoubts protect the turning and loading gear of the heavy 15-inch turrets. The armament consists of four 13-inch guns, eight 8-inch guns, four 6-inch guns, twenty 6-pounder rapid-fire guns, six 1-pounder guns, two Gatlings, and six torpedo tubes. This represents a weight of armament superior to that of any of the latest battleships laid down by other powers.

The 13-inch guns are seventeen feet eight inches above the water, and have large arcs of train and, unlike the English guns, which must return to the middle line to load after each fire, they are able to load in all positions, so that the muzzles can always be kept pointed toward the enemy. The 6-inch guns are mounted in 5-inch armored sponsons. The 8-inch guns are in armored barbette turret mounts, and are twenty-five feet above the water. They can fire over the tops of the 13-inch guns, and fourteen degrees across the middle line. These guns can pierce, at two miles, the armor of most armored cruisers. With their great height they can be brought into action early in the engagement, and can be used with terrible effect against the lighter armored and unarmored portions of heavier battleships.



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THE MINNEAPOLIS MAKING 23.073 KNOTS.

Special attention has been paid to the ammunition supply, and by means of longitudinal passages below the protective deck and special magazines under each gun emplacement, all confusion will be avoided and the service of powder and shell can go on without the slightest exposure of those handling it. A rapid, efficient and thoroughly protected supply has thus been secured, and one which, it is believed, is an advance upon all systems in vogue.

The powerful secondary battery is protected, in part, by shields, built in the vessels, and, in part, by shields carried on the mounts, and is so dis-

posed that a stream of projectiles will radiate from the vessel which will lead to the almost certain destruction of any light vessel venturing within range. All

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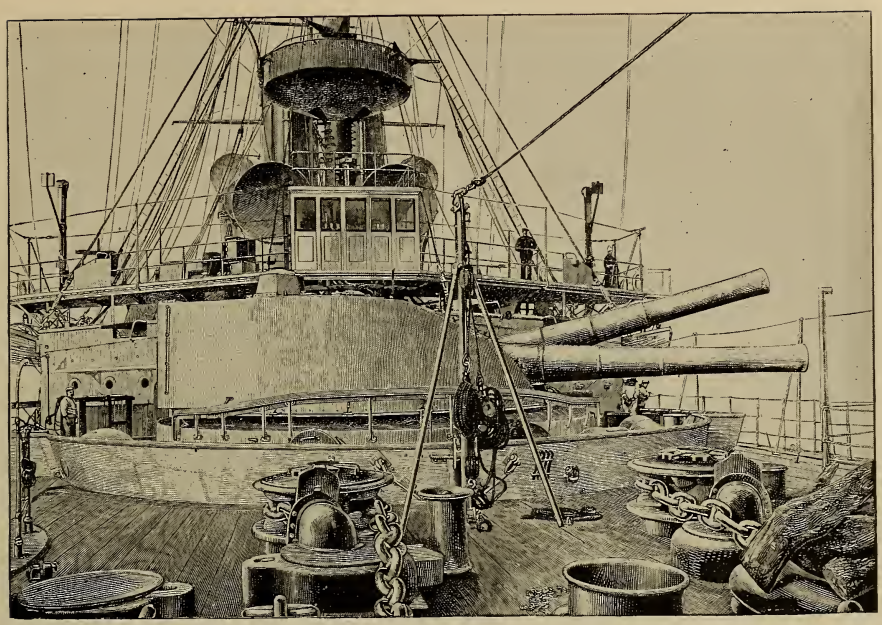
THE PROTECTED CRUISER MINNEAPOLIS—THE FASTEST PROTECTED CRUISER IN THE WORLD.

modern appliances for offensive and defensive purposes, such as torpedo defenses, search lights, etc., are carried, and weight has been reserved for any new fittings or devices which the constant progress in the art of war is continually developing as the work progresses. Great care was taken in disposing the battery that one gun should not interfere with the line of fire of another. The boats have been stowed amidships where the blast cannot reach them, and special strengthening has been given to the sides and decks that they may withstand the great strains brought upon them by the fire of the



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THE FORWARD BARBETTE OF H. M. S. BARFLEUR.

large guns. The 13-inch guns are six feet above the deck at the middle line. An armored conning tower, ten inches thick, is built forward, having an armored tube to protect the communications by means of which the commanding officer will direct, in battle, the movements of the vessel, guns and men. The speed will be fifteen knots sustained at sea, with a maximum speed of sixteen and one-quarter knots. The vessels can stow over 1800 tons of coal each.

The Columbia is a first-class protected cruiser, capable of making twenty-three knots speed, and with a coal capacity of over 2000 tons. She has three screws and is capable of developing 21,000 horse-power. While she could not successfully compete in speed with a vessel like the Campania across the Atlantic she could, once having sighted her at sea, catch her. The Columbia was followed by a sister ship, the Minneapolis, in every respect her equal. Both are 412 feet long, fifty-eight feet beam and displace 8000 tons on twenty-four feet draft. The armament consists of one 8-inch rifle, two 6-inch rifles, eight 4-inch rapid-fire rifles and a number of smaller rapid-fire guns, together with five torpedo guns. The protection is afforded to the vitals, such as machinery and ammunition, by a steel turtle-back-shaped deck, and to the water line by coal and a belt of obturating cellulose. The 8-inch and 6-inch guns are protected by shields attached to the gun carriages, and the 4-inch guns by armored sponsons.

The successful trials of the earlier cruisers have prepared the American people for the wonderful results attained in the speed trials of the New York, Olympia, Columbia and Minneapolis. When the nineteen-knot cruisers were projected the speed asked for was regarded as very high and those who guaranteed it were considered as almost reckless. It is safe to say that when the Columbia was contracted for, the speed expected to be attained over twenty-one knots was a very uncertain quantity, and both the contractors and the Government would have been greatly relieved to know that the twenty-one-knot speed was safe. While other nations seem to be satisfied to obtain the records for their vessels by

U. S. S. MONTEREY TAKING A BOW WAVE ON HER TRIAL TRIP.

spurts over a mile course or by patent log, American vessels can gain a record only by runs made in the open sea over accurately measured courses of many miles in length. No jockeying can be kept up over such a course for four hours with high-powered machinery.

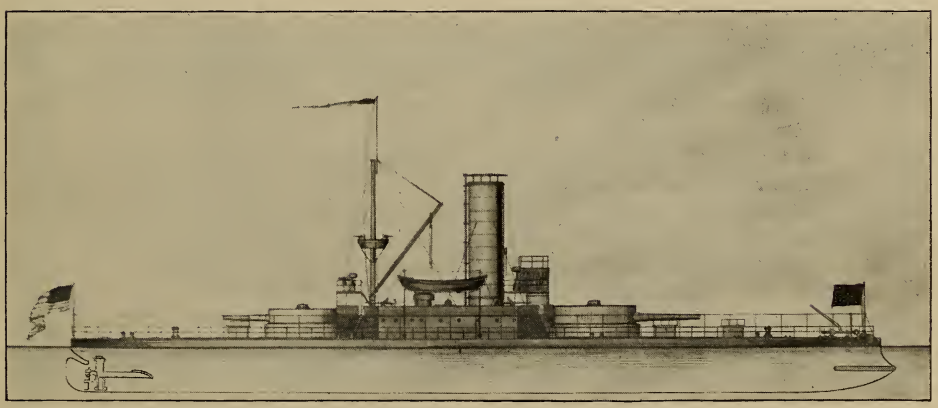
Of the monitors, the Monterey and Miantonomoh are in commission. These have their heavy guns mounted in armored turrets. The Puritan and Amphitrite have the combined barbette and turret known as the Hichborn emplacement. The Terror has turrets similar to those of the Miantonomoh, though the guns and turrets are to be worked in her case by pneumatic power.

The widespread interest taken in the United States navy has led to the establishment of naval militia by a number of the States. The present administration is encouraging this movement in every way possible and, with the most excellent results already attained, it is safe to say that the naval reserves will, in time of war, form an addition to American sea power, which will be well trained, efficient and instantly available.

Although public opinion in America has been wrought up, of late, over the armor question, there seems to be no doubt that the armor which has been delivered is among the best in the world, and that ships protected by it are perhaps even better armored than those of any other nation. The irresponsible charges against the stability of American vessels have been investigated, and ships of all classes are now regarded as fully seaworthy, so that this agitation, which at one time threatened to injure the hold of the vessels upon the popular mind, which depended, as everything American must depend, upon their being the best of their kind, has died a natural death.

The next great addition to the navy was made by the authorization in 1892 of the battleship Iowa and the armored cruiser Brooklyn. The Iowa is a larger

vessel than the Indiana, and while her guns are lighter and her armor belt is thinner, she has a greater freeboard forward and a knot more speed. The Brooklyn is a modified New York, having 1000 tons more displacement with the same power, two more 8-inch guns, making two such guns on each broadside, in turrets instead of in barbettes, and carrying twelve 5-inch quick-firing guns instead of the twelve 4-inch guns in the New York. The contracts for building the Columbia, Minneapolis, Iowa and Brooklyn were awarded to the Cramps. The other



U. S. S. MONTEREY.

ships now building are three gun boats of about 1200 tons displacement each, under construction at the Newport News Ship Building and Dry Dock Company, Newport News, Va. Two of these are especially engined for service in the shallow Chinese rivers. They are named the Penguin, Porpoise and Albatross.

Three navy yards have been put in condition to build vessels, the Norfolk, Brooklyn and Mare Island yards, but the main province of such yards will be to make repairs, as vessels cannot possibly be built in them as cheaply or as quickly as by contract.

The United States Naval bill just passed unfortunately has no new battle ships, but does provide for three torpedo boats by diverting an existing appropriation for a new Vesuvius, to that purpose. There are also appropriations still available for constructing a 23-knot torpedo chaser and a submarine torpedo boat, which vessels should be built.

The navy at present needs more battleships and more gunboats. The number of battleships should be brought up to at least a dozen and the number of first-class armored cruisers to six. Their maintenance need not cost much money, for at every navy yard there is an old wooden hulk used as a receiving ship, the repairs on which would keep a battleship in good condition. They should be replaced by battleships which, having a crew on board at all times, could be kept in the highest state of efficiency, ready at any time to go forth to battle.

One battleship or armored cruiser and a few of the larger vessels of the Baltimore class should be on every station, but the greater part of the important work which falls to the navy in time of peace, could be done more economically by small gunboats. These boats should be of about 990 tons displacement, thus keeping their allowances down to that of fourth rates. They should be of composite construction up to the water line, have about eleven knots maximum speed, and carry about four 4-inch rapid-fire rifles, with a number of smaller guns. They should

have ample sail power to permit them to do the greater part of their cruising under sail.

It is not uninteresting here to make note of the fact that the naval officers who have been at the head in this great naval renaissance are :

Chief constructors, Theodore D. Wilson and Philip Hichborn ; engineer-in-chief, Geo. W. Melville ; chiefs of ordnance, Commodores Montgomery Sicard, Wm. F. Folger and Wm. T. Sampson.

Since the beginning of the new navy the Navy Department has been administered by Secretaries Wm. E. Chandler, William C. Whitney, Benjamin F. Tracy and Hilary A. Herbert.

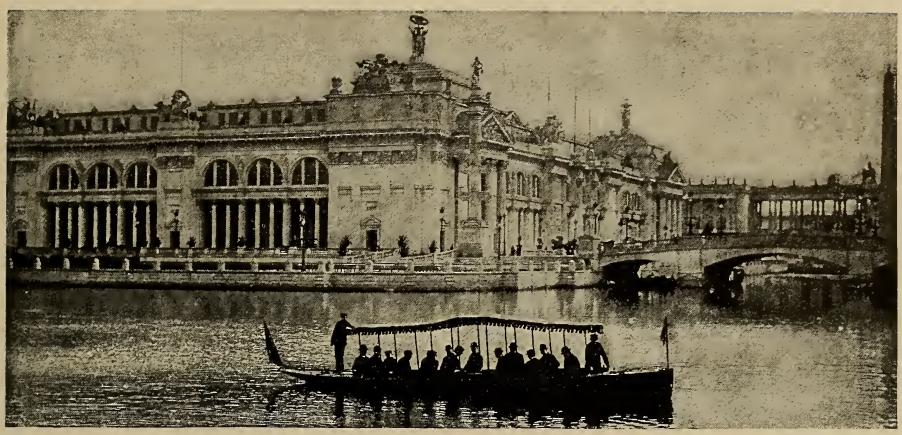
Mr. Chandler began the new navy with four splendid ships and awakened public sentiment to its support.

Mr. Whitney brought about a continuous naval policy and domesticated armor and gun making and other industries that were necessary to make the Government self-contained in shipbuilding, and made it possible to replace the wooden ships by powerful steel protected cruisers.

General Tracy, by his strong advocacy, brought the battleship and the first-class cruiser to the front, introduced Harveyized nickel-steel armor and gave the United States a *war* navy.

Secretary Herbert, who had aided in all the above as member and chairman of the naval committee of the American House of Representatives, finds himself with many of the plans of his predecessors matured, and all the great problems in connection with financing, manning, coaling and handling our growing fleet before him, together with the necessity of constantly adding to the number of ships already in existence.

There are now in commission or actually under construction forty-five new vessels—twelve gunboats, Petrel, Yorktown, Concord, Bennington, Machias, Castine, Penguin, Albatross, Porpoise, Detroit, Montgomery and Marblehead ; ten protected cruisers, Atlanta, Boston, Chicago, Charleston, Baltimore, Newark, San Francisco, Philadelphia, Raleigh, Cincinnati ; three first-class protected cruisers, Columbia, Minneapolis and Olympia ; three armored cruisers, New York, Brooklyn and Maine ; five battle ships, Indiana, Massachusetts, Oregon, Iowa and Texas ; six monitors, Puritan, Miantonomah, Terror, Amphitrite, Monterey and Monadnock ; four special types, Dolphin, Vesuvius, Katahdin and Bancroft ; two first-class torpedo boats, Cushing and Ericsson. The total displacement of all these vessels is 180,478 tons. They carry ninety 4-inch, sixty-eight 5-inch, 126 6-inch, sixty-six 8-inch, twenty-two 10-inch, twelve 12-inch and twelve 13-inch rifles, making 396 guns in all. In addition to these they carry 550 small rapid-firing guns and three 15-inch dynamite guns.



AN ELECTRIC LAUNCH AT THE WORLD'S COLUMBIAN EXPOSITION, 1893.

# SOME POSSIBILITIES OF THE STORAGE BATTERY.

*By Pedro G. Salom.*

THERE are few subjects that have excited more general interest and widespread speculation than that of the storage battery. From the wildest vagaries of the enthusiasts, who predict that, in the future, storage batteries will be so improved in capacity and efficiency, that it will be necessary only to occasionally have a few cells of battery at one's house, in order to supply an unlimited amount of light or power, that locomotives will be able to run hundreds of miles with a few hundred cells, and that ships will cross the Atlantic; we turn to the gloomiest forebodings of the pessimist, who can reason only from the failures and difficulties of the past to further trials and tribulations in the future. Inasmuch as storage batteries are likely to play a not unimportant part in the future development of electrical science, a proper understanding of the general principles underlying the subject may perhaps remove many popular errors and misconceptions.

A storage battery, or electric accumulator, is an apparatus for the transformation of energy. There is no such thing as storing electricity, and the current of electricity obtained from a storage battery after charging is derived solely from the chemical reactions taking place within the battery. This being the case, therefore, there is nothing mysterious about the operation of a battery, and it is self-evident that the limitations of its power must be directly proportional to the amount of material entering into its composition, which is subject to chemical changes within the battery itself, although from the extravagant claims that are sometimes made for different forms of battery, it might be supposed that the designer had discovered some method for creating energy out of nothing. Fortunately, we are able to measure to a nicety the exact amount of energy to be derived from a given combination of substances, and such claims, therefore, deceive only the credulous and unwary

speculator. There are an infinite variety of forms of storage battery, all of which resolve themselves into two general types, in the first of which, known as the Planté type, the active material is produced by the disintegrating action of the current on a portion of the plates themselves, and in the second, the active material is applied directly to, or combined with, the conducting supports.

A number of different materials have been used in the composition of the plates, but the modern storage battery —the one which is in most general use —consists almost entirely of lead and lead oxides, and the plates composing it are grids, in and upon which the oxides of lead have been mechanically applied.

The modern storage battery is the joint but independent invention of Charles F. Brush and Camille A. Faure, although Brush has been awarded the priority of invention in the United States by the highest Court of Appeal. Prior to their inventions, in 1859, Gaston Planté made a very interesting and exhaustive study in what might be called the parent form of storage battery, although the real germ of the invention must be awarded to a French chemist named Gautherot, who, as far back as 1804, discovered the reversed currents obtained from plates which had been previously electrically acted upon. It was not, however, until the time of Planté that any attempt was made to store the electrical energy from an outside source by means of a battery or accumulator.

The original Planté battery consisted of plates of lead which were repeatedly and alternately acted upon by a current of electricity, first in one direction and then in the opposite one, until a certain proportion of the lead had been converted into oxide of lead and spongy lead. When two lead plates are placed in dilute sulphuric acid, and their terminals are connected with the opposite poles of a dynamo, or some other source of electricity, and an electric circuit is made, oxygen is generated, through electrolysis, on the plate connected with the positive pole, and hydrogen on the plate connected with the negative pole. The oxygen attacks the plate of lead and combines with it, forming a thin coating of peroxide of lead, the hydrogen on the first charge escaping as hydrogen gas.

The plate connected with the positive pole is called the positive plate, and that with the negative pole, the negative plate. If now the current is reversed and the positive pole is attached to the former negative plate, this, in turn, becomes coated with a thin coating of peroxide of lead, but the hydrogen which is liberated now at what was the former positive pole, instead of merely passing off into the air, acts upon the thin coating of peroxide formed by the original charge, and reduces it to spongy lead. The current is again reversed ; the spongy lead produced by the second charge is peroxidized, and a further oxidation of the lead plate takes place. This operation is continued for a great number of times until the coatings thus formed are sufficiently large to do a useful amount of work, and the battery is then said to be "fully formed." In order to overcome this tedious operation of formation, it occurred to both Brush and Faure that inasmuch as the peroxide of lead and spongy lead were the useful parts of a battery, that if they could be applied directly to the lead plate, the plate acting in this case merely as a conductor, all the useful effect of a storage battery could be obtained at once without the necessity of the tedious process of formation, and this was the real invention in the Brush–Faure type of battery.

Brush took the oxides of lead and rammed them into grooves, which had previously been made in the lead plate, while Faure took the same oxides and, mixing them with a little dilute sulphuric acid, plastered them first on the surface of a plain sheet of lead, and afterward into various forms of lead supports in the shape of grids or plates provided with other receptacles which would retain the active material. The oxides were then in some cases reduced to spongy lead by chemical means, or the plates put directly into circuit with

the dynamo, and the oxides converted into peroxide of lead and spongy lead, after which they were ready to generate a current of electricity on having their terminals connected.

As has been said above, the current derived from a storage battery is produced by purely chemical means. If a piece of zinc be placed into dilute sulphuric or hydrochloric acid, a violent action immediately takes place with the evolution of hydrogen gas, and the generation of a definite amount of heat. If, however, we connect this piece of zinc with a copper wire, the end of which is also placed into the acid, the wire becomes endowed with the extraordinary properties which are produced by what we call an electric current, and as this phenomenon appears, the generation of heat in the acid disappears. It has been found, after the most careful investigations and research, that the electrical energy measured in foot-pounds, derived from the consumption of a pound of zinc in a battery, is exactly the same as the amount of energy in the form of heat, measured in foot-pounds, that is produced by the burning or combustion of a pound of zinc, showing conclusively the correlation of these two physical forces.

The electrical energy derived from a storage battery is, therefore, due to the electrical burning or combustion of the lead, of which its active part is composed. In the case of a lead storage battery the product of combustion, sulphate of lead, is not soluble in the acid or what is technically termed the electrolyte. One pound of lead has a theoretical potential energy of about 0.15 of a horse-power. But in order to utilize in a battery a pound of lead, which must be in a spongy condition, five pounds of solid lead and oxide of lead are necessary, and even then only one-half of its potential energy can be taken out as useful work before it becomes necessary to recharge the battery. Of course, the remaining 50 per cent. is not lost, but it is retained as a surplus, like the water in a tank which is allowed to discharge one-half its contents and is then filled up again.

If then we know the amount, by weight, of spongy lead and peroxide of lead, or that of any other equivalent active material, we have an absolute means of measuring the maximum capacity of any given cell for furnishing electric energy for a given time, and thereby determining the limitations of its usefulness. The source of the electro-motive-force of a battery, whether primary or secondary, is primarily dependent on the relative positions that any two elements or substances occupy in the electrical scale. By the electrical scale is meant the systematic arrangement of all elements and compounds beginning with the most electro-positive substance, and passing to the most electro-negative substance, in the order of their degree of intensity with which they possess one or the other of these properties. Each substance in the scale is electro-positive to the substance immediately below it, and electro-negative to the substance immediately above it; the substances at the beginning and end of the scale exhibiting, of course, electro-positive and electro-negative qualities in the highest degree.

The metals, as a rule, make electro-positive elements, and the non-metals, oxides and chlorides, etc., make electro-negative elements. Or, in other words, the various chemical affinities which these substance have for each other determine the electro-motive-force of the couple. This varies from the smallest fraction of a volt to about 3 volts, and in ordinary secondary batteries averages about 2 volts. In order to get any desired electro-motive-force above 2 volts from a battery, it is necessary to couple the elements in what is commonly termed "series," that is, to have a number of them whose poles are connected to each other alternately negative and positive, which makes the electro-motive-force cumulative, similar to the winding of an armature, whereby the electro-motive-force is increased in proportion to the number of turns of wire passing through a given field of force.

One of the most important applica-

tions for storage batteries is found in connection with electric lighting. Electric lighting with such batteries may be divided into isolated lighting and central station lighting. All isolated installations that are now being run night and day can advantageously and economically be improved by the addition of a storage battery, and the continuous operation of a dynamo thus be dispensed with, as well as the services of an extra engineer. When plants are not run night and day, owing to the great expense which it is impossible to avoid in operating a few lamps before and after the hours of maximum load, it is necessary to use gas or other source of illumination. This is a ridiculous and unnecessary humiliation to the owners of a costly installation, when a few storage batteries only are required in addition to the plant which they already possess to make it available day or night.

When lamps are supplied direct, the machinery must have a power capacity equal to the maximum number of lamps, and since the lamps are usually needed only a few hours a day, the plant will remain idle the rest of the time. Moreover, the engine and dynamo must be of the best construction and design, steady and quick regulating, to prevent flickering or variation in candle-power. But with storage batteries the generator is not limited as to the time or manner of working, and can prepare its supply slowly, ahead of time, during the day, in the many hours at its disposal ; and in addition to its requiring only a dynamo of very much smaller size, the machinery may be of much simpler and cheaper construction, for with the battery, irregularities in movement can exist without in any way affecting the quality of the light. The current from the accumulators is always uniform and regular, even while the charging current is subject to marked fluctuations. The storage battery is, in fact, an equalizer and regulator to the dynamo, besides acting as a reservoir in case of accident, liable to happen with the best machinery.

In all cases, a direct lighting plant can be made complete and perfectly reliable, by the addition of storage batteries, as the surplus energy, which can be stored while the dynamo is running under light load, can be utilized during the remaining hours of the day or night. With water or gas, we cannot expect a reliable supply without providing facilities for storage. In the profitable and practical application of electricity, we must also have a means of storing to insure an absolutely steady and uniform current, so necessary with incandescent lighting, and also to provide against any possibility of the extinguishing of the lights by failure of the generating plant.

The problem of domestic lighting has been solved by the introduction of storage batteries. Heretofore, electric light was only obtainable in localities adjacent to a central station, but by the application of accumulators almost any power can be made available. In places where an arc circuit is already installed, the introduction of the incandescent light becomes a comparatively simple and inexpensive matter. The arc dynamos can be used in the day time to charge the batteries, and at night to supply the arc lamps, while the stored, electrical energy is used to supply the incandescent lamps.

As an accessory to direct lighting in mills, or other manufacturing establishments, hotels, office buildings, schools, institutions and public buildings, the advantages of the use of storage batteries are too apparent to admit of argument. They furnish light when the power is shut down (which is usually at six o'clock), for office work, watchmen, storerooms and warehouses, for repairing and rearranging machinery, boilers, engines, shafting, etc., which in many cases has to be done at night. They will also furnish power for running electric motors, when other sources of power are stopped, as at night, or on Sundays or holidays.

The advantages to be derived from the use of storage batteries in an isolated electric light installation, when once fully recognized and appreciated by electrical engineers, will render their

introduction well-nigh universal. They may be summed up as follows: Light and power on tap at all hours of the day or night; the ability to add incandescent lighting to an arc system already installed; increase in life of lamps due to perfect regulation of the current, thus effecting a great saving in lamp renewals; as an auxiliary to direct incandescent lighting, where it is not possible or practical to keep the generating machinery in continuous operation; ease of manipulation and freedom from annoying breakdowns and other mechanical irregularities; the battery may be charged from either arc or incandescent circuits by the introduction of proper automatic safety switches and rheostats; the utilization of the current for many household conveniences, such as the running of fans, sewing machines, clocks, electric bells, pumps, etc., etc.; economy obtained by dispensing with an extra engineer for night work, and by obviating the necessity of running a large engine and dynamo for lighting a few lamps during the day or night, or before and after the time of maximum load.

The ideal electric lighting for country homes, is to be able at all hours, night or day, to turn on one or the full quota of lamps, with a never-failing supply of electricity, without the annoyance and expense of running the generating plant all night. This can be obtained only by the use of storage batteries, in which sufficient energy is stored during the day, according to the amount required for the twenty-four hours. Where steam power is not available, or is otherwise objectionable for charging batteries, a reliable, safe and economical power is a good oil engine, which is so simple to manipulate that an ordinary workman or gardener may be educated in a few days to safely operate and attend it.

One important point to be remembered is that with a storage battery the generating machinery need be only a fraction of the size required for direct lighting. Inasmuch as the work done in an isolated plant does not average more than three hours per lamp per day, or, say, for a 100-light plant, three hundred lamp hours, it is manifest that a 50-light dynamo running six hours will accomplish the same work through a storage battery, as a 100-light dynamo running direct.

The advantages of using storage batteries in central station lighting may be briefly summed up as follows:—They effect a substantial saving in operating expenses; they increase the factor of safety; they permit of a material extension of distribution without increasing the size of the power plant. Since the question of economy is largely the determining factor in considering the advisability of introducing a battery, let us examine more at length the means by which economy may be effected:—
1. By taking care of a sudden and excessive load when all the generating machinery is taxed to its utmost extent. 2. By dispensing with one shift of labor in taking care of the entire minimum load. 3. By permitting the operation of large units exclusively. 4. By operating all the units at their maximum load and, hence, their maximum efficiency.

Owing to the peculiar nature of electric lighting it frequently happens that the number of units generated at the maximum load is not more than a few per cent. of that of the total average load, and the total load is only a few per cent. in summer, and rarely above forty per cent. in winter, of the total possible output of the plant.

The first requisite in determining whether a battery can be advantageously introduced in any given central station, and if so what its size or capacity shall be, is to have diagrams of the load curves. The next important factor is the number and size of the units employed at the station. From these data can be determined what has very appropriately been called the load factor, and then it is simple to calculate the size of the battery required to give the most economical operating results. Once the size of the battery determined we can calculate the saving effected:—
a. By dispensing with a night shift;
b. By diminishing the consumption of

coal for a given output; c. By the saving effected by operating a few large units of one size, instead of a number of small units of various sizes; d. By the saving effected in operating each unit at its maximum efficiency; and e. By the additional revenues from increase of total output taken from battery at time of maximum load.

As the item of labor in small stations is frequently as high as twenty-five per cent. of the operating expenses, the saving effected by dispensing with a night shift is not inconsiderable. By operating exclusively large units, there is also a material saving both in labor and the much higher efficiencies of large over small units. Again, as the coal bill is the largest item of expense, amounting in some cases to fifty per cent. and over of the total operating expenses, any saving effected in this item is of paramount importance, and is reflected at once in the decrease in operating expenses.

The question of mechanical efficiency with varying loads has not been as carefully studied with each type of engine as its importance deserves, but Professor W. Cawthorne Unwin has shown that the decrease of mechanical efficiency for light loads has a serious effect on the economy of working with a variable load, and that with a load varying from one hundred to twenty-five per cent., the efficiency decreases from eighty-five to forty per cent. While it is impossible to say in a general way what the exact saving would be from the introduction of a battery of sufficient size to permit of the operation of all the units at maximum load (since the load is not the same in any two central stations), the results prove that in central stations equipped with storage batteries, the operating expenses are diminished as much as thirty per cent.

As to the factor of safety, in case there is a derangement or break-down of the generating machinery, or where the steam pressure cannot be kept up to a sufficiently high point to operate all the units at maximum load, the elasticity of a storage battery permits of an immediate discharge rate enormously in excess of its normal rate. In other words, a battery designed for a given output could, in emergencies, be safely called upon, for one-half hour or more, to deliver a current three times as great as that for which it was designed.

This is a question of vital importance, as in any direct system of transmission there is always the liability of a derangement or break-down of one of the links in the chain, whereas in a station equipped with a storage battery, the manager can depend on the battery to take the load of an individual unit until such time as the derangement or break-down can be remedied or repaired. Moreover, it frequently happens, where the business of a station has increased since the original introduction of its generating machinery, that the boiler capacity at maximum load is so taxed that it is difficult to maintain steam pressure sufficient to operate all the units at once. In such a case, if a battery is employed, recourse may be had to the battery until such time as the engineer shall be able to keep steam up to the required pressure.

As regards distribution, it is evident that when a central station, for example, has supplied the demand within a given radius of economical distribution, and a demand arises for electric light or power immediately adjacent to and outside of this given radius of distribution, it is possible to supply this demand by having sub-stations of storage batteries which may be charged by a special wire at comparatively high pressure during the day, thus increasing the average load of the central station. At night the current may be distributed from the sub-stations at the regular pressure, thus enabling the central station to materially increase its revenues without increasing its original power plant. There is an economy also effected in this method of distribution by decreasing the size of the feeders to the out-lying districts. This is accomplished by being able to charge the batteries used at a comparatively small rate for ten or twelve hours, whereas,

by lighting direct, the feeders would have to be large enough to carry the entire load of the sub-station at its maximum output, which might last only for two or three hours.

Besides the saving effected in operating expenses, the use of a battery may be made to yield additional revenues in proportion to the amount of current supplied to the circuit over and above what could be supplied by the direct system, at the time of maximum load, without increasing the size of the power plant.

From what has been said above, it is evident that central station lighting is one of the most important fields of usefulness of the storage battery, and one which has hardly yet been touched upon.

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## PRODUCER GAS FOR STEAM RAISING.

*By W. H. Blauvelt.*

WHILE it is very desirable that the firing of boilers should be smokeless, it is at the same time important that it should be economical, as smoke preventing devices will receive scant encouragement from those who are to use them if they entail increased expense for fuel or attendance. In fact, it is the economy of any proposed method that will alone determine its acceptance by the steam user. We have then, in considering the use of producer gas for firing boilers, to first discuss the question of its economy in comparison with the ordinary methods of firing; and, second, whether the prevention of smoke can be accomplished by its adoption.

In a paper on the subject, presented a short time ago before the Engineers' Society of Western Pennsylvania, the author directed attention first to the often made statements that the losses incident to gasification are so great that gas can never be an economical fuel for this work, that the heat generated in burning the carbon to carbon monoxide is lost in the producer, and that regeneration cannot be used to repay these losses, as is done in the regenerative furnaces for steel making, etc. While these statements may have been true with the earlier types of producers and in former practice, they no longer obtain with present methods. Let us see what the losses actually are, and whether there are any corresponding ones in direct firing that will balance them. For this purpose let us assume the gasification, in a producer of the most modern type, of a coal containing, say, 55 per cent. of fixed carbon, 32 per cent. of hydrocarbons and 13 per cent. of water and ash.

In all modern practice steam is mingled with the air used for blowing the producer, the principal object being to absorb the heat of primary combustion (burning carbon to carbon monoxide), which dissociates the steam, the hydrogen being set free and the oxygen combining with carbon to form carbon monoxide. A secondary object is the softening and breaking up of the clinkers formed. It is found that somewhat less that 8 per cent. of steam, by weight, is about the maximum amount practicable; in this mixture one-fourth of the oxygen needed for the combustion in the producer is supplied by the steam, the other three-fourths coming from the air. Assuming that 11 per cent. of the fixed carbon is burned to carbon dioxide, and that the above mixture of

steam and air is used for blowing the producer, 1 pound of the above coal will give the following gas :—

| | Pounds Gas. | British Thermal Units. Heat Devel. | Heat Absorbed. |
|---|---|---|---|
| 0.5 pound carbon burned to $CO_2$ | 0.183 | 725 | .... |
| 0.5 pound carbon burned to CO | 1.167 | 2,200 | .... |
| Total | | 2,925 | |
| 0.32 pound hydrocarbons, (distilled)* | 0.320 | .... | .... |
| 0.88 pound oxygen needed, of which 0.2 pound derived from $H_2O$ liberates H | 0.025 | .... | 1,550 |
| 0.60 pound oxygen derived from air is associated with N. | 2.007 | .... | .... |
| Total pounds gas from 1 pound coal | 3.702 | raised to 600 F. | 540 |
| Total | | | 2,090 |

*The hydrocarbons are assumed to be methane ($CH_4$).

The total energy in 1 pound of the above coal is 14,375 B. T. U. The difference between the heat developed and the heat absorbed (the loss by radiation, etc.,) is 2925 — 2090 B. T. U. = 835 B. T. U. = 5.8 per cent. of the total energy of the coal. The energy expended in blowing the producer amounts to about 2 per cent. of the energy in the coal gasified. Thus, with the most economical producer practice, the gas enters the flue with a loss of 7.8 per cent. charged against it. In a plant for firing boilers the producer should be as near as possible to the combustion chamber, and the additional radiation in this short flue would be hardly anything. If the gas lost 25° in temperature, it would amount to 0.2 per cent., making the total loss due to the gasification 8 per cent. In this estimate I have not considered the losses common to grate flues and producers, such as the carbon and sensible heat lost in the ashes, the heat expended in volatilizing the hydro-carbons, etc.

Now let us consider what are the relative values of the gaseous and solid fuels in the combustion chamber of the boiler. It is well known that gas can be burned with practically no more than the theoretical amount of air, if care is taken to mix them intimately. But it is shown by Rankine and others that at least twice the theoretical quantity of air is necessary to properly burn solid fuel, in order to provide for the proper dilution of the gases of combustion, which would otherwise prevent the free access of air to the fuel. Much more than this excess is actually used in practice, especially when we consider the enormous quantities of air that enter the doors during the operations of stoking and cleaning the fire. But for this comparison we will accept Rankine's figures, 24 pounds of air to 1 pound of coal.

To burn the gas from 1 pound of coal (assuming it to be of the composition given in the above table), 9.3 pounds of air are needed. Assuming for simplicity sake that the walls of the furnace radiate no heat, all the heat generated is absorbed by the boiler, except that escaping up the stack in the waste gases, which, we will assume, have the moderate temperature of 600° Fahrenheit. It will at once be seen that the loss from this cause is much greater in the case of the solid fuel, owing to the greater volume of the gases. The amount of the loss is shown below.

When gaseous fuel is burned, the gas enters the combustion chamber at 600° Fahrenheit, as before shown, and the air at an average of say 50°. Therefore the total loss of heat in the combustion under a boiler of the gas from 1 pound of coal is that absorbed in raising the 9.3 pounds of air from 50° to 600°, the temperature of the stack gases. This loss amounts to 1279 B. T. U., or 8.8 per cent. of the total energy of the coal. Adding this to the loss in the producer and flue, gives 16.8 per cent. as the total loss under the assumed conditions.

In the case of the solid fuel, both coal and air enter the combustion chamber at the temperature of the atmosphere, which has been assumed to be 50°. We have, therefore, 24.87 pounds of

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waste gases to be raised 550°. No account has been made of the moisture in the coal in either case, as its action is the same in both. This absorbs 3420 B. T. U., or 23.8 per cent. of the total energy in the coal. The loss is, therefore, 7 per cent. greater by the use of solid fuel than when gas is the fuel; or, 11,960 B. T. U. are available for work in a pound of coal, when burned as gas, and 10,953 B. T. U. when it is used direct. The gas would, therefore, do 9.2 per cent. more work than the solid fuel. These figures show only the losses essential to the two methods and which no care in manipulation can overcome. In practice there are other losses, such as that of carbon falling through the grate and the escape of unconsumed gases. The great variations in a grate fire in the proportions of air and combustible as fresh fuel is thrown on and then burns down to bright coals, is a serious cause of loss that is entirely lacking in the gas fire when properly handled.

That the results of practical tests comparing gas with direct firing vary greatly, often showing much larger and sometimes even less economy in favor of the gas than that shown here, is due to the relative approximations made to the above examples, which are of the best attainable practice. When hand fired boilers are badly managed, the economy obtained from gas, properly applied, is very large, sometimes as high as 30 to 35 per cent. On the contrary, when gas is carelessly and incorrectly applied to boilers previously fired by hand in the best manner, it may be that no saving will be effected.

The above calculation has shown what a large amount of heat is lost in the chimney gases, even when they escape at no higher temperature than 600° Fahrenheit. Gas fuel readily enables a portion of this heat to be returned to the combustion chamber by using the waste gases to preheat the air for combustion. The temperature to which the air can be raised depends upon the opportunity the arrangement of the plant affords for introducing an efficient heating apparatus. But in the case here assumed, if the incoming air could be heated to 325° (which could readily be done) one-half of the chimney loss, or 4.4 per cent. of the total energy in the coal burned as gas, would be saved, and the total loss reduced to 12.4 per cent., against 23.8 per cent. loss with the solid fuel.

Not the least among the advantages of gaseous fuel is the unquestionable fact that by its use it is much easier to maintain a maximum of economy, and the personal feelings of the firemen do not introduce so large a variable into the problem as in the ordinary method of hand firing. Therefore, gas-fired boilers usually give a much greater saving over those fired with coal than is shown in the above comparison. Tests made at various times and with widely different fuels show economies varying from 10 to 30 per cent., and in almost all cases a materially increased rate of evaporation is obtained.

Another important advantage is that the steaming is much more regular, especially when the plant is large. Then all the producers feed into a common gas main, and this supplies all the boilers, so that there is practically no variation in the supply of gas. The life of the boiler is materially greater with the gaseous fuel, as it is free from the strains caused by the frequent cooling due to the enormous quantities of cold air that rush in whenever the fire doors are open for the stoking and cleaning necessary when burning solid fuel. Just to what extent these strains shorten the life of a boiler it is impossible to estimate, but it is acknowledged that their effect is serious.

On the other side, the solid fuel has the advantage of the radiant heat of the bed of coals as it glows on the grate after being fully coked. Just what this amounts to is not known, nor have we been able to measure its evaporative value. It is undoubtedly true that more evaporation per square foot of surface can be obtained by a coal fire when there is a sufficiently strong draft than by gas, but only at a largely increased expenditure of coal, in proportion to the duty done. Notwithstanding the

undetermined value of the radiant heat from the solid fuel, numerous practical tests show the economy to be in favor of the gas, and this is a proof much more satisfactory to the steam user than the most elaborate and convincing calculations of thermal energy and absorption. As a result of our investigation into the economy of the subject we find, therefore, that the advantages are on the side of the gaseous fuel for firing boilers. Its use secures more duty per pound of coal, insures a higher average of good work, more regular steaming, and the life of the boiler is materially prolonged.

Turning now to the other branch of our subject, our first inquiry is, what is smoke, and how is it formed? Although smoke in general may be composed of a large number of gases, vapors and finely divided solids, we will consider only the smoke from bituminous coal; this may be defined as that portion of the products of combustion of the hydrocarbons in the coal which is visible, viz., solid carbon in a finely divided state, or soot, and volatilized but unburnt hydro-carbon.

Many hydro-carbons, when heated to suitable temperatures, are decomposed, with formation of a new hydrocarbon and solid carbon in a fine state, which, unless there is present a supply of air at a proper temperature for its combustion, passes off as soot. Smoke may also be formed by hydrocarbons while in combustion striking against a cool surface, which lowers the temperature below that at which combustion can be sustained, and the flame is "put out," with the production of smoke as the result.

A third cause is the distillation of the hydrocarbons without alteration or even partial combustion. It is this that gives the yellow tinge to smoke, and the greasy quality, which is one of its most disagreeable features. From the point of view of thermal economics, the formation of smoke is not of such serious importance as many imagine. In ordinary cases the actual loss of combustible amounts to but a few per cent. of the energy in the coal; in its denser forms it is important because it is the indicator of seriously imperfect combustion, and because carbon is visibly wasted. The attempt should be, therefore, to prevent its formation rather than to "consume" it, at the expenditure of mechanical or thermal energy.

The causes for the formation of smoke serve to indicate the means for its prevention. The deposition of solid carbon from decomposed hydrocarbons and the escape of unburnt volatilized hydrocarbons may both be prevented by their intimate mixture at the moment of combustion with the proper amount of air, preferably preheated, so that each particle of carbon or hydrocarbon may find oxygen adjacent to it for its combustion. The "putting out" of the flame by its contact with cold surfaces may only be overcome by permitting the combustion to be nearly complete or at least thoroughly established before the gases are allowed to impinge upon the boiler shell or other cool surface. While it is very difficult to carry out these conditions with solid fuel, gas easily lends itself to them, and by their proper application all smoke can be prevented from gas-fired boilers. The mistake usually made in applying gas to boilers is the attempt to imitate the conditions of a solid coal fire, it being forgotten that the gas is employed in order to overcome weak points essential to the use of solid fuel.

In some applications of gas recently made to return tubular boilers by the writer, a careful use of the above principles in the light of previous less successful experience resulted in the prevention of all smoke and in an increase of the evaporative capacity of the boilers of over 12 per cent. as compared with the results from the same coal burned on the grate. At the same time there was a saving of about 15 per cent. in the amount of coal used. The air for combustion was not preheated, and the temperature of the waste gases was 700° or more, as the boilers were too short for the most economical work. Had hot air been used, of course, this high stack temperature would not have been a source of serious loss. The

mixture of the gas and air was made as prompt and perfect as possible by a special arrangement of the ports, and inflammation was thoroughly developed in a brick chamber below the boilers. This was so arranged that but little more than the products of combustion reached the shell of the boiler, and at the same time the temperature at which combustion took place was kept high by the reflected and radiated heat from the walls of the chamber. For successful boiler firing it is essential that the mixture of gas and air should take place as soon as possible after they enter the combustion chamber. Frequently they are introduced in parallel streams, but even if these streams are small, the gas and air often travel quite a distance with but little mingling of the currents. This is an important point.

The arrangement referred to above provoked some criticism from onlookers, as the fire seemed too far from the boiler to those whose idea was that the conditions of a coal fire should be imitated as closely as possible. But the entire absence of smoke and the duty obtained from the coal, both as to economy and rate of evaporation, were sufficient arguments in proof of the correctness of the principle employed. One point noted during this test was that it was practically impossible for the firemen to make smoke except by the most gross inattention to the relative proportions of air and gas.

I know of no other method of burning fuel which presents so practical and reliable a solution of the smoke problem ; for it not only makes no smoke when carefully operated, but is equally free from that fault when the fireman's vigilance is relaxed, and it adds to this the advantage of economy over the methods in general use. To make gas available for the steam plants in the business parts of cities a special producer would, in many instances, be required, of a design suited to the limited quarters that it would have to occupy, but this would hardly be a serious obstacle. Smoke abatement in cities is occupying so much public attention that stringent legislation on the subject is sure to come, and much annoyance and loss to steam users may be avoided by putting themselves beyond liability while there is ample time to make the change.

THE EDGAR THOMSON STEEL WORKS AND BLAST FURNACES AT BESSEMER, PA.

# HOW IRON IS MADE.

*By John Birkinbine, Past Pres. Am. Inst. M. E.*

Second Paper.

ALTHOUGH iron is largely used and much has been written concerning the method of manufacture, and the appliances utilized to produce it, the arrangement of plants or processes employed are not generally understood except in districts where this branch of industry is a prominent feature. The process of manufacturing pig iron as carried on in blast furnaces consists of smelting the ores, for these, being, as a rule, practically infusible, cannot be melted until the oxide of iron has been "reduced" by gases resulting from the partial or complete combustion of fuel; subsequent to such "reduction" comes the melting process and the separation of the resulting metal and slag. This slag being of lighter specific gravity than the iron, floats on the molten metal in the blast furnace hearth, and can be tapped off as it accumulates. It also serves as a protection to the iron by preventing the blast from entering the furnace and oxidizing the metal.

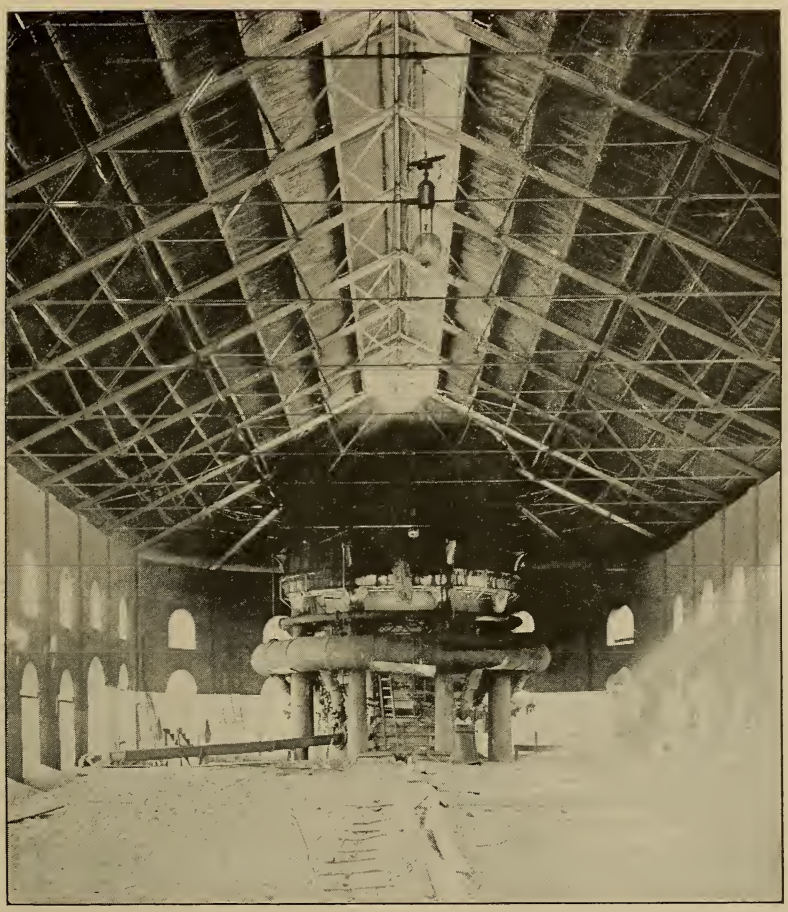
A modern iron blast furnace plant may be described as consisting of from one to nine furnace stacks situated either near to a desirable market, and where the requisite raw materials can be assembled, or in closer proximity to supplies of fuel, flux and iron ore, having good transportation facilities to a market. Each stack is composed of a shell or casing made of sheet iron or steel, which is carried on iron columns so as to give around the base of the structure opportunity to "work" the furnace. The shell is lined with firebrick to form the inwalls or shaft, and the portion inclosed within the column circle is built of similar masonry, suitably braced, stayed and water cooled, to form the hearth and boshes. Some stacks are built so that the masonry of the inwall of the furnace is held by bands or a series of metal bands and bars, forming an open bracing, instead of the continuous casing or shell. Experiments are now being made with material even more refractory than ordinary fire brick, placed in the hearth and boshes of blast furnaces.

The raw materials are brought by railroad cars which are run into a large building or "stock house," the ore, fuel and flux being dropped into their respective pockets or bins, or are discharged from vessels onto storage docks. Unless the iron ore and limestone have been so treated in advance, the larger pieces are generally reduced in size by a crusher or rock breaker before being fed to the furnace. If the ores contain sulphur to any considerable extent, if they are carbonates, and in some cases where there is an excess of water, they are roasted before being charged into the furnaces, and nearly all of the bituminous coal used is coked. These raw materials are either loaded by hand or discharged from pockets into "barrows" which are pushed by laborers to the foot of a hoist tower, where they are elevated by steam, water or air pressure to the platform surrounding the top of the furnace known as the "tunnel head," and dumped on the bell closing the furnace throat, by lowering which the materials are delivered into the furnace, and are there distributed. The bell, closing against the hopper, forms a seal to prevent the gases from escaping from the tunnel head, and diverting them into the conduits leading to hot ovens and boilers. While the terms "bell

and hopper" are generally applied to this apparatus, "cup and cone" are also used. The mechanism for handling the bells is quite ingenious, and in large furnaces is powerful. In some instances cars, running on an inclined plane, convey the stock either in barrows or in large skips to the top of the furnace, and where such skips are used they are automatically discharged.

A feature of possible economy which has not received the attention it deserves is the handling of material in stock houses, or from wharves or stock piles. In some plants laborers propel barrows loaded with iron or fuel or flux from the loading point, an average of fully 350 feet, to the foot of the hoisting plant, and must return an equal distance. In one large plant such work is reduced by a system of flat trolley cars operated by electric motors. The barrows being placed on these cars near the bins, the navvies who load them are relieved of the labor of propelling them to and from the hoist tower, and the time otherwise required is available for filling other barrows. But with the predominance of large furnaces, a number of which require the handling of over 1000 tons of raw materials per day for each stack, the system of hand barrows adopted when smaller amounts were demanded, seems out of place. Improvement in this particular appears to be in the direction of using vehicles holding a ton or more which can be moved by power, and of assembling the charge at the stock room level, lifting it in bulk to and discharging it into the furnace throat, by suitable mechanical appliances. This method now followed at several furnaces will evidently grow in favor with plants constructed or remodeled in the future.

As the top of each furnace is closed by a cone or bell, fitting against a hopper ring, the gases formed by the combustion of the fuel are diverted into one or more large tubes, termed "down takes," having near the ground level "dust catchers," in which the heavier particles carried over are deposited, and subsequently carried away. From these dust chambers the gas is conveyed in pipes to the boilers and hot blast stoves where it is used as fuel. The number of boilers and hot blast stoves varies at different furnaces, but, as a rule, there are connected with each furnace three hot blast stoves and sometimes a fourth, the latter being held in reserve, and boilers sufficient to generate steam for blowing engines, pumps, hoist, etc. Many furnaces are equipped with hot blast stoves consisting of a series of iron pipes set in chambers, so that, being surrounded by the flame from burning gases, the air passing through the pipes is highly heated. Most of the hot blast stoves now erected, however, are built of fire-brick, with a sheet metal casing, and vary from 15 to 24 feet in diameter, and from 40 to 80 feet in height. The gases entering a combustion chamber are there burned, the products of combustion traversing narrow passages, or checker work, of masonry, raising this to a high temperature. The gases are then shut off from one stove and the air from the blowing machinery is passed through the hot chambers or checker work, absorbing sufficient heat to elevate it to the desired point. If three such stoves are in use, the gas from the furnace is generally burning in two of them, heating the mass of brick work to the requisite temperature, while through the passages of the third stove, which has reached the necessary degree of heat, the cold air is being forced and is raised to, in some instances, as high a temperature as 1400 degrees Fahrenheit. The air then passes on through the hot blast mains to the circle or "bustle pipe" which surrounds the lower part of the furnace, from which it is distributed into the tuyere pipes or stocks leading to from 5 to 8 tuyeres by which the heated air finally enters the furnace, supplying the oxygen necessary for the combustion of the fuel. The practice at most works using fire-brick or regenerative stoves is to change the air from one stove to another every hour, so as to keep it at a nearly uniform temperature. That is, the gases are burned in



IN A CASTING HOUSE.

each stove for two hours and blast passed through them for one hour. Where iron pipe stoves are employed, the air passes through the pipes constantly, and the gas is burned under or about them continuously.

The high temperatures attained in modern practice demand that the valves about the fire-brick stoves be protected by water cooling or air cushioning, and that the main pipes, bustle pipes, and tuyere stocks through which the highly heated air passes, be lined with fire-brick or otherwise relieved from damage or excessive radiation. To preserve the fire-brick masonry of the lower portion of the furnace, metallic rings are inserted in it, or jackets surround it, these rings or jackets being formed so that water passes through pipes or through partitions in them, keeping the masonry at as low temperature as possible and thus extending its life. The blast enters through tuyeres which are water cooled, and these generally fit into breasts similarly arranged. Cinder is tapped through an opening kept cool by water, and the dam from which the iron flows from the furnace is protected in like manner, while all around the hearth or crucible, and often on the boshes, large quantities of water are applied by jets or sprays. The supply of water for a modern blast furnace is, in fact, no inconsiderable item.

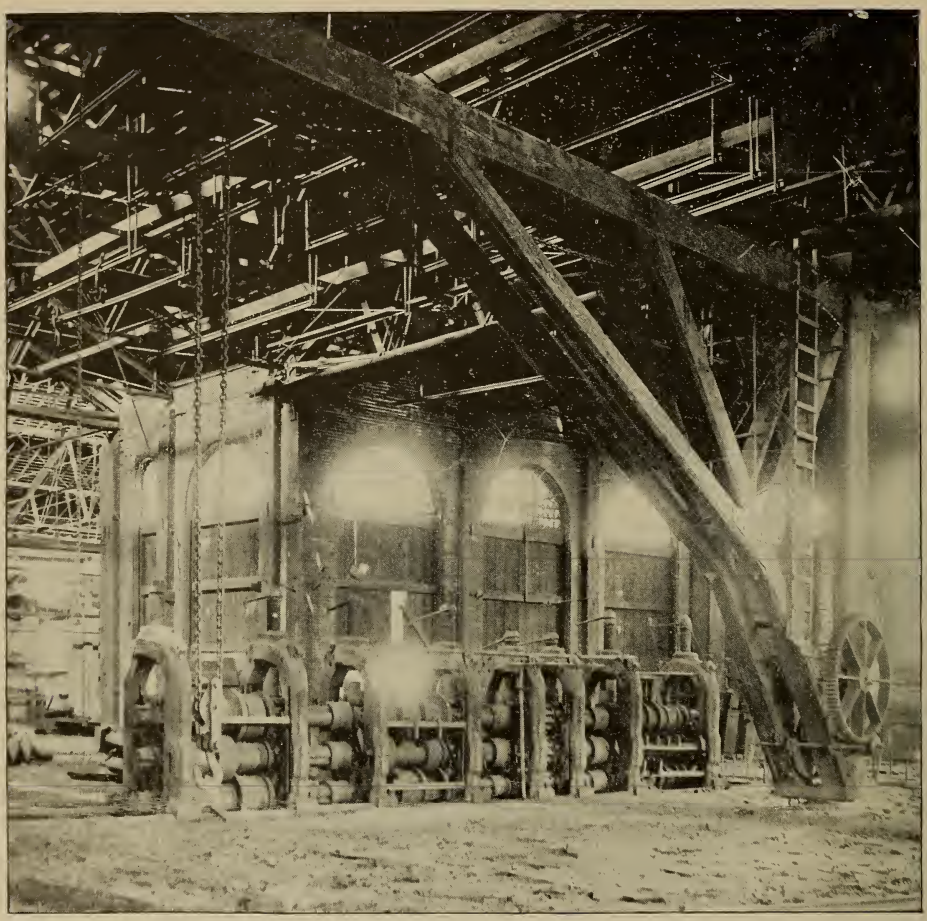
RUINS OF AN ANTE-BELLUM FURNACE AND BLOWING APPARATUS IN THE UNITED STATES.

As the smelting of the ores proceeds and iron is produced, it drops into the crucible, and the gangue from which it is relieved unites with the flux to form cinder, which, being of less specific gravity, floats on the iron, and protects it from oxidation. As the cinder accumulates, it is tapped off, and every six or eight hours the iron is drawn out. The cinder runs either into the cinder molds, or into cars, by which it is taken to the slag pile, while the iron runs in a trough made through the centre of a large building known as a cast house, the floor of which, being of sand, is filled with molds, connecting with the main trough by means of auxiliary channels, or "sows." The molds which are the final receptacle for the molten metal, being attached to the sow, are known as "pigs." When cold, the pigs are broken from the sows, graded and piled for shipment. In some large plants the metal runs directly from the furnace into cars by which it is removed in a molten state for further treatment. The handling of molten slag in ladle cars grows in favor, requiring less labor to handle a given quantity of cinder and less space for slag dumps, which generally are waste piles. However, slag is not always waste, but is broken up for railway track ballast, or for road metaling, and paving blocks are made of some of it. By applying a jet of water to a stream of liquid cinder, free from iron, the material is granulated and answers the purposes of sand; a jet of steam similarly applied produces fine glassy threads, which, when collected in suitable chambers, forms a good non-conducting filling known to the trade as "mineral wool."

There are numerous buildings, in addition to those named, connected with a blast furnace plant, one of which contains from one to twelve powerful blowing engines, used to drive the air through the receivers and cold blast pipes to the hot blast stoves, and thence to the furnace. Of the engines more will be said later. There is a boiler house or shed, generally containing the boilers required to supply steam for the blowing engine, pumps, hoisting engine, electric light plant. There are also the necessary buildings for office, laboratory, scales, smith and carpenter shops, pump houses, stables, etc. Such a plant demands numerous railroad tracks equipped with switches, signals, scales, etc., to facilitate the handling of raw materials, cinder, and the shipment of the product.

To emphasize the above general description of a modern blast furnace plant in the United States, the following data are presented concerning a blast furnace plant which the writer visited in Central Mexico in 1893. The iron works is situated in a "barranca," or deep valley crossing an extensive plain, within two miles of a range of rugged hills, from which most of the wood is cut for making charcoal for the blast furnace and for smith fires. Encino (oak) is used for the former, and ocote (pine) for the latter. The plant, which is inclosed by a high "adobe" wall, or isolated by the vertical sides of the adjacent "arroyo," consists of an extensive group of buildings, with adobe, or masonry walls, and steep shingle roofs, the cedro (cedar) shingles being secured by wooden pins which project several inches. The number and extent of the buildings, and their arrangement on the steep hillside, indicate a manufactory, but the only suspicion of an iron works is in the chimneys of the blast furnace, and the foundry cupola extending beyond the roofs, through which flame or smoke is vented.

The blast furnace which was erected about 1835, is a square masonry stack, similar in design to the older cold blast charcoal furnaces of Pennsylvania. The lower portion is built of stone masonry, the upper of "adobe" or mud brick, the structure being braced by wooden "vigas" (beams) with ends mortised, tenoned and keyed. The crucible and boshes are laid up as a monolith, with a stiff fire-clay concrete, firmly rammed, and the inwalls are formed with "fire stone," hewn into blocks and laid in clay. Spawls from these blocks, mixed with fire-clay and sand, form the mono-



A THREE-HIGH ROLL TRAIN.

lithic hearth and boshes above mentioned which last during a campaign of from nine to twelve months. Monolithic hearths are not unusual in Swedish charcoal furnaces, but they are not used in the United States. If properly made, they should be equally as efficient as those formed by fire-brick laid as in general practice.

The crucible of the furnace is 24 inches square, and 22 inches high, the front opening into a fore hearth, 48 by 24 by 22 inches, closed by an iron dam plate in which are iron and cinder openings. Two tuyeres enter from opposite sides at the top of the crucible, being D-shaped castings in which the nozzle is inserted. Neither the tuyeres or the dam are water-cooled, nor the tuyere nozzles luted in the tuyere with clay. At a height of 5 feet from the bottom, the boshes change from a square section to a circular one, 8 feet 2 inches in diameter at the top. The tunnel head is inclosed by three sides of a square chimney to catch sparks. The furnace may, therefore, be briefly described as operating cold blast, with open top, a bosh diameter of 8 feet 2 inches, a height of 34 feet 5 inches, blown by two tuyeres. Air is supplied by two horizontal iron cylinders, 42 inches in diameter by 3 feet 6 inches stroke, operated by a water-wheel, 32 feet in diameter by 4 feet face. This wheel also furnishes power for a machine shop.

Charcoal, ore and limestone are brought to the works in sacks, on the backs of mules, burros or Indians. The average load for a mule is from 10 to 14 "arrovas" (250 to 350 pounds); for a burro or jack, from 8 to 10 "arrovas" (200 to 250 pounds); and for an Indian, from 4 to 6 "arrovas" (100 to 150 pounds). All the material is bought by weight, an inspector weighing and examining each sack as it is emptied into bins. Indian women break up the ore and limestone to nut size, being paid by the wheelbarrow-load, two cents for ore, and four and one-half cents for stone. The broken material is discharged into a lower series of bins at the same level as the charcoal houses and furnace top. From these bins the top fillers deliver the materials to the tunnel head of the furnace, the ore and flux in boxes, carried by handles, and the charcoal in tenates (sacks of raw hide), which, when filled, are swung on the backs of peons to be thus carried to the furnace throat. The ore is brown hematite, yielding about 35 per cent. of iron, and brought from five to eighteen miles. It is obtained from small excavations and is imperfectly prepared. The charcoal is made in open heaps at points from two to five miles distant from the furnace, and is much broken by handling. The limestone is quarried about two miles from the plant.

The casting house of the furnace is the foundry floor, for but little pig iron is made, most of the iron being tapped from the furnace into ladles, and from these poured into various molds. The character of the direct castings is good, and the metal apparently satisfactory; in fact, the furnace is run to make castings, pig iron being produced only when extra metal is tapped, or on Sundays, which is a holiday rather than a day for worship. There is also a cupola in the same building, used when the furnace is idle, or to make special work; but railings, cog-wheels, plow points, plow shares, die plates, fire hydrant cases, and even water pipes as large as 80 centimeters (31.5 inches) diameter are run from the furnace direct.

A charge for the blast furnace is from 800 to 850 pounds of ore, 60 pounds of limestone, and from 350 to 400 pounds of charcoal. The men employed about the furnace and foundry earn from 43 cents to one dollar Mexican per day, ordinary peon labor commanding 3 reals (37½ cents) per day. The weekly product is from 400 to 450 quintals (40,000 to 45,000 pounds) of iron, and was, at the date of my visit in March, 1893, hauled eight and one-half Mexican "leguas" (twenty-two miles) to a railroad station, seventy-five miles from the City of Mexico. Later extensions of the railroad shorten the present wagon haul five miles. Heavy wagons, carrying from six to seven tons, are used, and to these teams of fourteen Mexican mules are hitched, there being two mules at the pole, and three rows of four mules abreast. The Mexican mules, which are small but tough, are the almost universal draught animals. This furnace is managed in connection with another, forty miles beyond, in the mountains, which converts its pig metal into wrought-iron by puddling it with pine

A CHARCOAL BLAST FURNACE.

wood as fuel. This wrought-iron is hauled in two-wheeled carts, carrying from two to two and one-half tons, and drawn by seven mules. While this sketch describes how iron is now made at some of the Mexican iron works, and for that reason has been given in

AN AMERICAN BLAST FURNACE PARTLY HEWN FROM A ROCK-LEDGE.

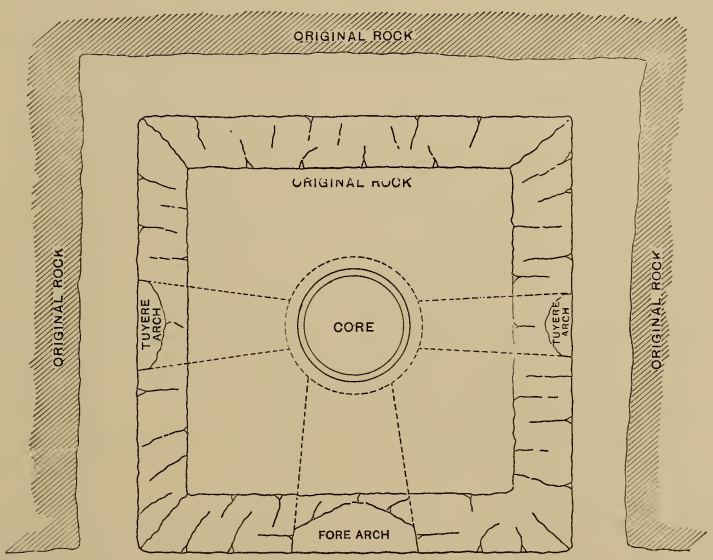
more detail, it has also been introduced as indicating the structures, and to some extent the practice prevalent in the United States half a century ago. There are plants of more modern construction in Mexico, but the one described was selected as showing, by comparison with the former sketch, variations in present practice.

The American blast furnace of fifty years ago was built of stone, or was hewn from the solid rock and was operated with an open top. The fuel used was charcoal; ore and flux were charged by hand from boxes, and charcoal from baskets. One or two open tuyeres delivered the cold air into crucibles, square in section; cinder was allowed to run continuously after it had once reached nearly to the tuyere level, and iron was either tapped from a fore-hearth for pig iron, or ladled from this receptacle for producing castings. The employment of adobe in place of stone is a peculiarity of Mexican structure and the custom of "packing" materials on the backs of animals or laborers was not followed in the United States, most of the transportation in this country being by wheeled vehicles, although some of the mountain furnaces sent iron to market packed on the backs of mules. The blowing appliances at the Mexican furnace described is a duplicate of some which were in use in this country to within a few years.

Starting a blast furnace was formerly an occasion of great importance to the community settled about it, and was naturally associated with more or less superstition. Some of the older founders would consider the presence of a female at the furnace when its preliminary charge of fuel was being lighted an evil omen, and any subsequent bad work would be ascribed to the innocent sister. *Per contra*, in later times the practice has often been to invite, as a compliment, the wife or daughter of a prominent officer of the iron company to light the fire when a blast furnace was starting on a new campaign. The older practice was to fill a blast furnace entirely with charcoal, lighting it at the top. When the fire had worked down to the hearth the tuyeres were inserted and the blast was applied, fuel being added with increasing quantities of ore and sufficient flux until normal working was secured. Finding that this resulted in a hot top and cold hearth, while the reverse was required for good work, furnaces were filled with charcoal, except the hearth into which kindling was placed, and, after lighting at the bottom, nothing was done until the fire had worked through to the top. Then fuel, ore and flux were added and the blast was driven into the furnace. Subsequently, particularly where mineral fuel was used, the hearth was filled with kindling, cordwood occupying the space up to the "bosh" or greatest diameter of the furnace; then came a large bed of coke or coal and flux, followed by

more fuel, together with increasing quantities of ore, the blast being held in reserve until the mass was well on fire. Each of the methods described occupied days, and sometimes a week was consumed from the time of lighting to the application of blast, but later practice is to use the air from the engines soon after lighting to stimulate the fire, at first in small volume, increasing as indications favored such increase, so that a few hours now suffice for what was formerly believed should take days.

Too great precipitation may of course do harm, particularly when a large mass of green masonry has been put into position in the furnace, but good practice requires a thorough and somewhat protracted drying out of the furnace before it is charged for a campaign, for, when once started, a blast furnace is expected to run continuously




PLAN OF A FURNACE HEWN FROM THE SOLID ROCK.

day and night, week days, Sundays and holidays, year after year. In this country the more rapid driving of our iron furnaces shortens the length of campaigns, and two or three years is unusual, although furnaces have been in continuous operation for six or seven years, this being nearer the English average. But in the shorter campaigns common in the United States fully as much iron is produced without relining the stack as is taken from an English furnace during the longer blast.

Failure to secure a nearly uniform ignition often results in unsatisfactory campaigns, hence, although the formality connected with starting a blast furnace is now less pronounced, a good manager devotes much study to the details of the filling and firing. In this connection attention is invited to an interesting circumstance. A blast furnace at Port Henry, N. Y., was prepared for a campaign, and from one and a half to two feet of cordwood were placed on the boshes to protect them from abrasion by the anthracite coal, coke, ore and limestone, thrown down in large quantities from the tunnel head. At the close of the campaign, when the furnace was cleaned out, much of this wood, converted, of course, by the intense heat into charcoal, "was found as placed, in a vertical position, strongly compacted together, but by no means crushed. It was protected by a fine dusty, carbonaceous covering (small coal and coke in part), and, as found, was not sealed up with cinder, though

this had flowed over it at some time, as the cracks in the charcoal were often found filled with it. In thickness it was about twelve inches. The material that passed through this wooden bosh amounted to 136,159 tons of coal, coke, ore, and stone, in two years, and the best work done by the furnace was during this period."

A manager's anxiety does not cease with the starting of the furnace. He must be constantly vigilant, attentive to minor details, ready for emergencies, and a competent man soon learns to judge with a degree of exactness, surprising to the uninitiated, of the work which is being done within the furnace and to foresee results which will follow. Where continuous operation is necessary, all features of construction and equipment must be of such character as to decrease the stoppages to a minimum, and as the production of individual furnaces has augmented, the appreciation of this has become apparent to those owning or operating plants. In a blast furnace which produces three hundred tons of iron per day, a cessation of operations for five minutes causes a loss of a ton of metal, and any decrease in the average output advances the cost of iron produced, because interest, salaries, fixed charges, and generally wages are practically constant. The best results in fuel consumption and character of product also usually follow operating a furnace close to its capacity ; therefore, it is essential that the construction, equipment, and management should be such as to maintain the furnace in constant activity. To secure this, good material and machinery of approved design must be used, and all parts kept at a high standard of efficiency.

Assuming that a blast furnace, well constructed and equipped, has been filled and successfully started, it will be of interest to follow the process through a campaign. The "blowing in" may be considered as ending when the first iron is successfully run, the output generally being small, and unless the stack is thoroughly heated and the proportions of the charge decided upon with intelligence, the want of fluidity of the metal is apt to prove troublesome. As the campaign advances, all parts of the furnace become more highly heated, and larger quantities of ore can be charged on a given weight of fuel, thus permitting a reduction in the cost of iron made in proportion to the decreased fuel consumption. As the quantity of fuel burned in the hearth practically determines the capacity of a blast furnace it is evident that a decreased consumption per ton of iron made permits of an increased output in a given time.

The material fed into the furnace is divided into "charges" based on a given quantity of fuel, the proportional amount of ore being regulated according to its character and the quality of product desired. In addition to the ore, limestone sufficient to flux away the impurities in the ore and fuel is introduced to complete the charge. Thus, using, say, 4000 pounds of fuel as a basis, a specimen charge may be described as consisting of 4000 pounds of fuel, 7500 pounds of ore and 1500 pounds of limestone. In this case the "burden" would be considered 7500 on a fuel charge of 4000 or in the proportion of 1.875 to 1, with 20 per cent. of limestone.

The direction of a blast furnace plant is in the hands of a manager or superintendent, his chief assistant being the "founder," to whom is delegated such details as seeing that the proportions of ingredients decided upon are fed to the furnace, so as to keep it well filled, regulating the volume, pressure and temperature of the blast according to directions, and the condition of the furnace, maintaining a careful record of the operation of all parts of the plant, and giving general oversight to its working. A "keeper" and assistants are stationed at the base of the furnace, busied in watching the process going on within the crucible through peep-holes in the tuyere stocks, keeping the tuyeres clear of cinder, tapping the cinder and iron at appropriate intervals, and generally molding up the pig beds and running iron into the

molds. Frequent inspections through the tuyeres and examinations of the color, viscidity and fracture of the cinder removed at each "flush," taken in connection with the character of gas produced, the volume and pressure of air recorded at the blowing engines, and its temperature, as it comes from the hot blast stoves, permit of determining, within narrow limits, the quantity and grade of iron which will be cast, and one of the founder's duties is to be on the alert to detect and report any irregularities. The engineer and assistants have in charge the blowing engines, pumps and other machinery, and the operation of the boilers, while the equipment of hot blast stoves is delegated to men specially drilled to utilize the gases to best advantage, and to maintain a nearly uniform temperature of blast. Gangs of men, directed by foremen, unload the cars of raw materials, roast or crush such as may be necessary; others, called "bottom fillers," shovel the materials into barrows and deliver them, after being weighed, to the hoist platforms, returning with empty barrows; still others, stationed at the tunnel head, and known as "top fillers," take the loaded barrows from the hoist, dump their contents on the furnace bell and return the empty barrows to the hoist. In and about the casting house other employees break the pigs from the sows, handle them to scales, grade them according to directions, and place them on piles for stock or on cars for shipment. Where metal is run into ladle cars, the pig-bed is used only in case of emergency or on Sunday when the converting works are idle.

Although the railroad companies deliver the loaded cars and remove the empties from blast furnace sidings, the work of shifting, taken in connection with the handling of cinder to appropriate points of deposit, is sufficient at a moderate sized plant to keep a locomotive busy, and large plants have an equipment of such engines.

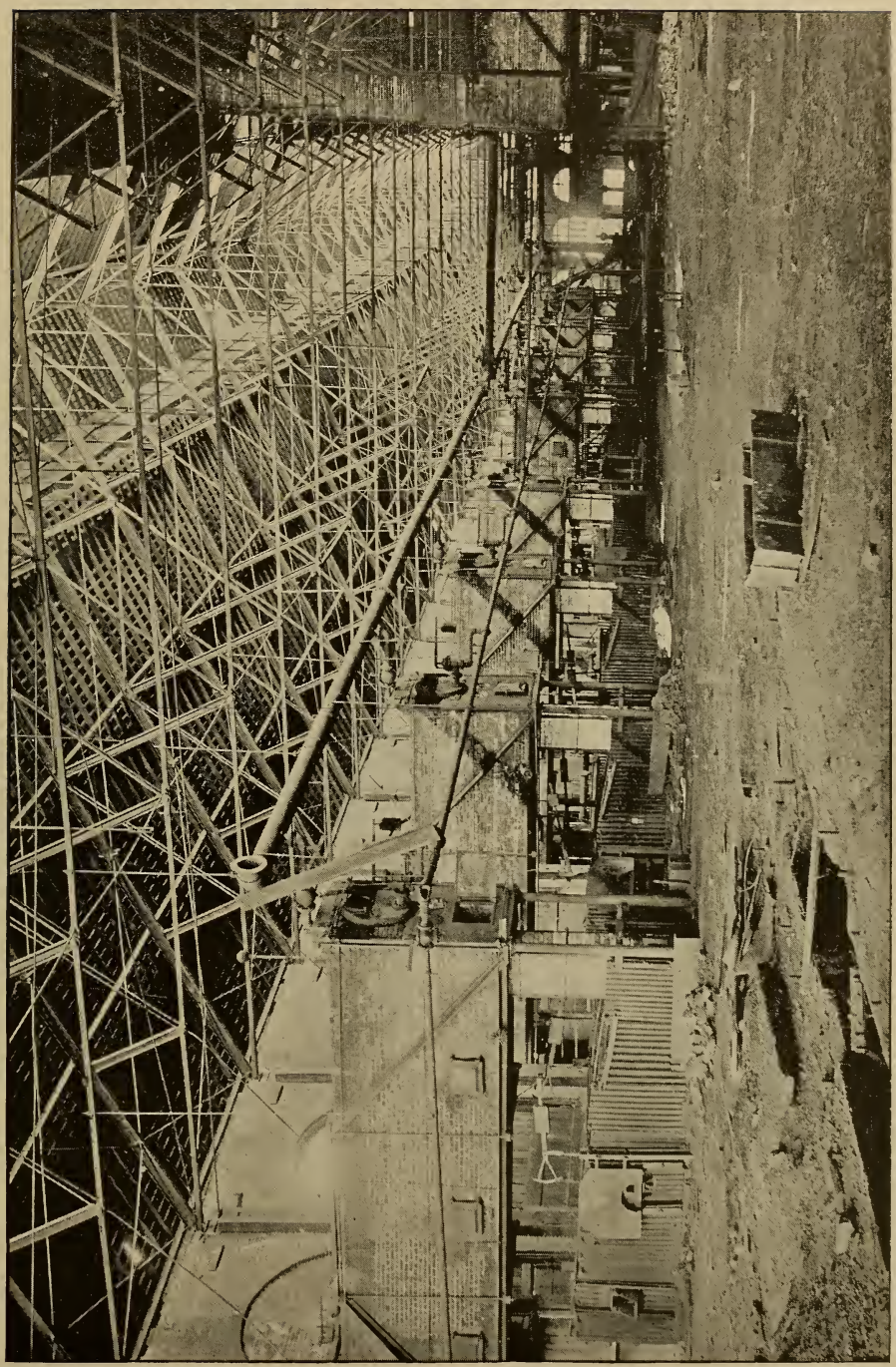
The above would seem to indicate that a manager's duties were largely within the office. This is far from the case, for although he has considerable demanding his attention within doors, it is essential that his presence should be noted around the works at frequent intervals, and that he should be perfectly conversant with all the details of operation, directing these through subordinates specially intrusted with certain of them. In the office the manager has to attend to the necessary correspondence, which will insure obtaining supplies of ore, fuel and flux; ordering them in advance, watching their shipment, so that they may arrive in proper time to avoid unnecessary handling, and to maintain sufficient reserves of stock for emergencies, at the same time preventing such accumulation as would be disadvantageous. Bills for lubricants, tools, supplies, raw materials, freights, and the pay rolls must be examined and audited, and the reports, prepared daily, or, in many cases, twice a day, by those having special charge of details, must be analyzed and prepared for a general report. Consultation with assistants concerning various special features, and with the chemist as to the work of his laboratory, are parts of the daily routine, and it is seldom that a day passes but what a furnace manager must give some time to visitors or the ubiquitous drummer. To keep abreast of the times he must read the trade and technical publications, proceedings of engineering societies, etc. In some plants where the manager looks after the sale of the pig iron produced, his duties are augmented by the attention which a study of the market, and correspondence or interviews with or visits to his customers demand.

This refers to a blast furnace moving along regularly, but the multiplicity of parts about the plant, the close watchfulness of every detail demanded, to maintain continuous operation, and the widespread influence which some minor irregularity or defect may exert, are constant menaces against blast furnace management being considered a peaceful pursuit. A noted iron metallurgist who lost his life while endeavoring to correct an irregularity

in the working of one of the blast furnaces under his control, said to the writer while discussing the blast furnace problem,—"My greatest anxiety and my constant effort is to maintain regularity of operation in all parts of the plant, for a slight defect or disarrangement in one feature may result in great expense, loss of product and physical exhaustion." This epitomizes the purpose of a live blast furnace manager, and in some cases it is accomplished much more readily than in others. A manager who has a well-equipped plant, supplied with selected raw materials, and a market for all of his product, may have in a large plant of several furnaces less real anxiety than he who operates a single furnace of smaller dimensions, deficient in some of its equipments, or whose supplies of raw material are irregular in quantity or unsatisfactory in quality, and who must produce a specific grade of metal and find a satisfactory sale for it.

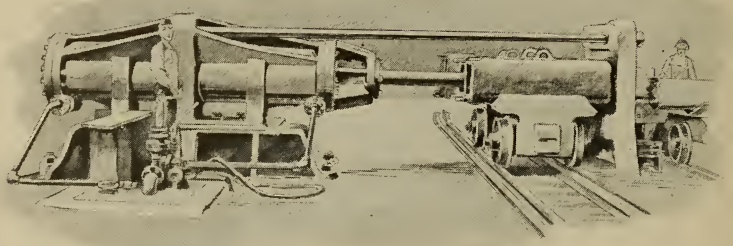
The direction of a blast furnace plant is not a bed of roses; it is a position of grave responsibility, and often of considerable personal risk, demanding constant and continuous oversight. While the manager's office hours may ostensibly correspond with the ordinary working day, he is, in reality, never off duty, and is as likely to have a night call as many physicians. During the campaign of a blast furnace numerous emergencies arise to disturb him. Should he fail to have a satisfactory "blow in," should the fire burn up one side of the stack and be retarded on the other, or should the material be sintered and accumulate on the boshes or inwalls, so that the stock fed into the top of the furnace does not flow regularly, or is imperfectly treated, the furnace is considered as "scaffolded," and then efforts must be made to dislodge the scaffold. Blank charges, *i. e.*, charges consisting of fuel alone, or fuel and flux, are introduced in large quantities, openings are made near the level of the supposed scaffold, and "monkey tuyeres" sometimes fed with oil spray, are introduced in the hopes of melting it, and in some cases dynamite in considerable quantity is discharged to dislodge the accumulation. As long as the scaffold exists, it is apt not only to interfere with the output of the furnace, and its fuel economy, but also to cause other serious disturbances, such as "slips" by which large quantities of material rush down unexpectedly in the furnace, often doing considerable damage by cinder or gas and necessitating exhausting and dangerous work about the furnace crucible.

To emphasize the necessity of continuous regular operation, it may be mentioned that momentarily stopping the blowing machinery without notice may result in injury which it will take days to repair, for in many cases where relatively high-pressures are blown, shutting off the blast would encourage cinder to run into the tuyere fixtures, and the entire system of these would have to be taken down and cleaned at considerable expense in time and labor, and, but for the intervention of valves, the furnace gases would find their way into the engine, and, meeting with flame, possibly explode with serious results. In fact, throughout the entire plant the gas must be kept under absolute control, directed to the proper points for combustion, and burned only there. Leakage of gas around the tunnel head fixtures may asphyxiate the top fillers. A chamber becoming filled with gas and air to which fire is applied, may cause destructive explosions, and yet, if properly managed and watched, this gas resulting from the furnace operation, is a safe and efficient fuel for use in hot blast stoves and under boilers, and is generally more than sufficient for the requirements of the plant. Any defect in the blowing machinery, accident to boilers, disarrangement of pumps, or of the hoisting appliances demand a cessation of operation. A leaky tuyere or cooling plate must be promptly removed, and this should be done by stopping the furnace for the smallest interval of time possible. As the campaign advances, the intense heat within the furnace, the attrition of the stock, and the dissolving action of the gases reduce the thickness of the



A ROW OF PUDDLING FURNACES.

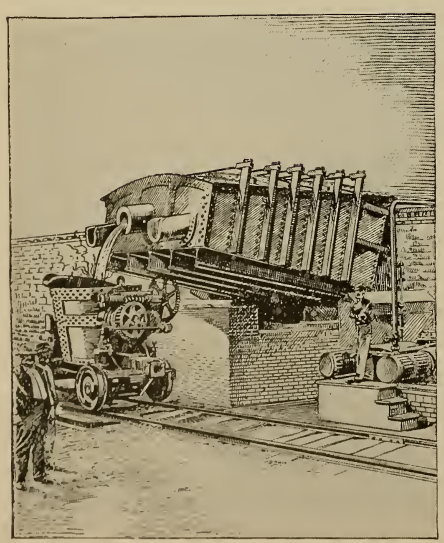
walls of the lower portion of the furnace, and although the inequalities are generally overcome by a carbonaceous deposit, the stability of the walls is reduced, and "break outs" through or under the masonry may occur, in which



PUSHER FOR REMOVING INGOTS FROM MOULDS.

case the molten iron flows out in considerable quantity, often to the jeopardy of property and life, particularly if the iron encounters water. In such a case explosions are apt to follow.

Even with the furnace working with apparent regularity, there may be fre-



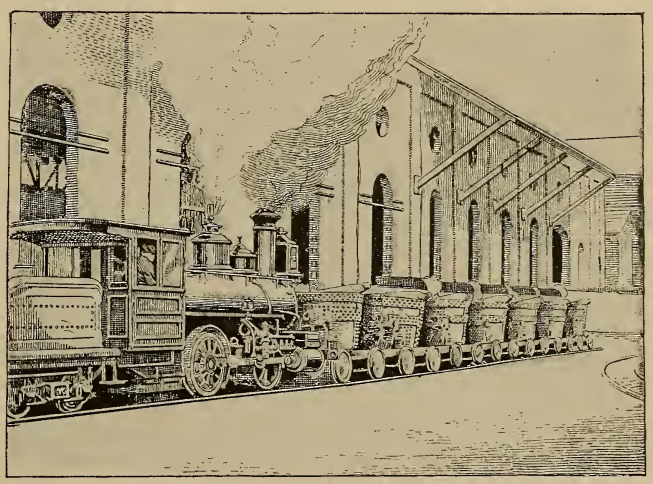
A METAL MIXER.

quent losses of tuyeres, chilled iron notches, boils in the pig "bed," etc., to disturb the manager. The chilled notch has demanded so much hard labor that latterly the introduction of a blow pipe with crude petroleum has met with marked favor, its purpose being to melt out the chilled hole, and a special power drill has been designed to take the place of numbers of laborers, striking against large bars with heavy "dollies." Often, in casting, if the pig bed is not properly drained, the iron comes in contact with water and causes explosion of greater or less intensity, and serious ebullitions which destroy a considerable portion of the pig bed, and produce a liberal allowance of unmerchantable scrap which must be recharged to the furnace.

After a campaign is finished, and the furnace is blown out, because of a falling market, by reason of scant supplies of raw material, or on account of the furnace walls being practically worn through, preparations for the "blow out" demand about as much care as for the "blow in." Of course, any accident or sudden emergency which demands the cessation of operations permits of no such preparation, but otherwise special care is taken to cool the bell and hopper, and spray the gases in the down-comers so that these will not be destroyed by the intense heat, and the charging and blowing of

the furnace is managed so that the material within the stack may, as far as practicable, be taken out in a liquid state through the cinder or iron notches. Otherwise there will remain chilled accumulations on the walls, jeopardizing the life of those employed to remove them, or a mixture of raw materials, fire-brick, etc., will form in the bottom. These "salamanders," as they are termed, often weigh many tons and are difficult to dispose of.

In case of any emergency arising which causes the suspension of operations, and where this suspension is believed to be but temporary, and sufficient time is given to the management to prepare for doing so, the furnace is "banked," *i. e.*, the molten iron and cinder are tapped from the furnace and the stack is practically filled with fuel, all ingress of air being prevented by luting with clay. Furnaces have stood in this way for a year or more, and have been started off again successfully, although, unless there is very good reason for believing the stoppage to be but temporary, the economy of banking is doubtful.



A TRAIN OF LADLE CARS.

Some of the accidents to, or disturbances at, blast furnaces demand heroic treatment, and call into action with great promptness the ability and resources of the entire force connected with the plant. Instances are on record where a practically new crucible has been constructed to replace one which was giving way, and this was done while the furnace was in operation. In other instances, the boshes or inwalls had been destroyed in one or more spots and these have been repaired. In still others the upper part of the furnace has given way and this has been rebuilt without suspending operations. The bell and hopper, closing the top of the furnace, have dropped into the structure and have been recovered, and numerous emergencies of a similar character have arisen and been met by the intelligence and hard work of those having charge of the plant.

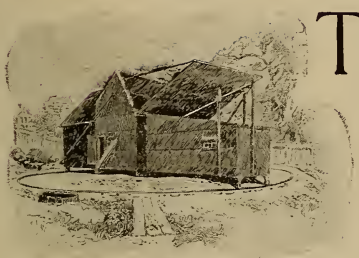
One of the demands upon the manager's time is the grading and sorting of the pig iron made. Although the extension of knowledge concerning the influence chemical composition has upon pig iron is most noticeable, the grading by fracture is necessarily largely employed, and this demands close attention and nice distinction. As the grain and color of pig iron is influenced noticeably by but few of the elements, and as the predominating features are the percentages of carbon which exist in graphitic form or combined, and of silicon, it is not unusual to find several different grades of iron in one cast, and the mere passage of the molten metal through cold runners may influence its grade. Except where the iron is taken from the furnace in a molten state in ladles, the general rule is to break the pigs from the sows in the beds by bars and sledges. Subsequently, the pigs are broken to determine the grade from the fracture, and for this purpose, as well as for ease in

handling from the pig beds to the stock pile, some ingenious appliances have been introduced. Unless the employment of liquid metal extends very rapidly, it is believed that the possibility of economizing in the labor of making up pig beds, removing, breaking, and grading the iron, will be in the direction of erecting a casting shed convenient to several blast furnaces, equipping this casting shed so that the pig iron can be molded and handled by machinery, either as pigs in flat molds or as small ingots in vertical molds, the entire operation of casting, handling, breaking, grading, being delegated to men specially skilled in this branch. The iron from the blast furnaces could be taken in the molten state by ladle cars to this casting shed, and its uniformity could possibly be improved by using an intermediate mixer as employed at some of the large steel works in which the molten metal from several furnaces is commingled. The application of some general plan like this would permit of erecting a group of furnaces as close together as would permit of men working about them and give facilities for bringing the raw material to them. Fewer men would be required about each furnace, and the dust annoyance and heat would be materially reduced. The mixer shown in the illustration on page 142 is an iron chamber capable of holding one hundred tons of metal, suitably braced, and lined with fire-brick. It is supported on trunnions, which permit of raising or lowering the front end by suitable machinery. From an elevated track ladle cars pour molten iron into an opening near the back, and, if desirable, the chamber can be oscillated to facilitate mixing metal from different blast furnaces.

The system of grading, adopted in different sections of the country and, in fact, at neighboring furnaces, varies greatly. Some recognize but four grades, which are known as Numbers 1, 2, 3 and 4. The first is the metal produced when the furnace is very hot and has the greatest percentage of graphitic carbon, the crystallization being large and distinct. The last is the product from a cold furnace, the carbon being in the combined form, and the fracture white and lamellar. Other furnaces have five, six, and as high even as sixteen grades, although iron seldom receives a number greater than five or six, the intermediate grading being distinguished by letters, half numbers or special names, such as "1A," "2B," "2½," "3½," "mottled," "silver-gray," "white," "open," etc. Under these conditions, and as the grading of iron introduces the factor of personality, there is little uniformity in the practice followed, and unless a purchaser is familiar with the peculiarities of the district, or of an individual furnace, he may find the grade of one producer to differ materially from a supposed similar grade of another producer.

# EDISON'S KINETO-PHONOGRAPH.

*By Antonia and W. K. L. Dickson.*



EDISON'S KINETOGRAPHIC THEATRE AT ORANGE, N. J.

THE initial idea of Edison's kinetoscope, relating to the reproduction of motion, is based upon the familiar toy known as the zoetrope or wheel of life. This rude prototype contains a cylinder ten inches in width and open at the top, around the lower half of whose interior a series of pictures is placed, representing any sequence of motion it may be desired to portray, such, for instance, as wrestling, jumping or the swift progress of animals. These movements are seen through the narrow vertical slits in the cylinder during the rapid revolution of the little machine, and are designed to blend into one continuous impression. In the zoetrope, however, the pictures are wood cuts of rude execution, and the limited speed attainable in the production of these militate against the life-like effect, producing a series of jerks instead of the desired continuity of motion. When instantaneous photography, as evolved by Maddox and others, was utilized, superior results were attained, but it seemed impossible to take pictures at sufficiently short intervals to secure the absolute blending of outline essential to a faithful portrayal of life. Matters were in this unsatisfactory condition when the resources of the laboratory were brought to bear upon the problem. Let us hear Mr Edison himself on the subject :

"In the year 1887 the idea occurred to me that it was possible to devise an instrument which should do for the eye what the phonograph does for the ear, and that by a combination of the two, all motion and sound could be recorded and reproduced simultaneously. This idea, the germ of which came from the little toy called the zoetrope, and the work of Muybridge, Marie and others, has now been accomplished, so that every change of facial expression can be recorded and reproduced life size. The kinetoscope is only a small model, illustrating the present stage of progress, but with each succeeding month new possibilities are brought into view.

"I believe that in coming years, by my own work and that of Dickson, Muybridge, Marie and others who will doubtless enter the field, that grand opera can be given at the Metropolitan Opera House at New York without any material change from the original, and with artists and musicians long since dead."

The synchronous attachment of photography with the phonograph was early contemplated by Mr. Edison, in order to record and give back impressions to the eye as well as to the ear. The comprehensive term for this invention is the kineto-phonograph ; the dual "taking machine" is the phono-kinetograph, and the reproducing-machine the phono-kinetoscope, in contradistinction to the kinetograph and the kinetoscope, which relate respectively to the taking and reproduction of movable but soundless objects.

The initial experiments took the form of microscopic pin-point photographs, placed on a cylindrical shell, corresponding in size to the ordinary phonograph cylinder. These two cylinders were then placed side by side on a shaft and the sound record was taken as near as possible synchronously with the photographic image impressed on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the sensitive surface of the shell. The photographic portion of the undertaking was seriously hampered by the defects of the materials at hand, which, however excellent in themselves, offered no substance sufficiently sensitive. How to secure clear-cut outlines, or indeed any outlines at all, together with phenomenal speed, was the problem which puzzled the experimenters. The Daguerre, albumen and kindred processes met the first requirements, but failed when subjected to the test of speed. These methods were therefore regretfully abandoned, a certain precipitate of knowledge being retained, and a bold leap was made to the Maddox gelatine bromide of silver emulsion, with which the cylinders were coated. This process gave rise to a new and serious difficulty. The bromide of silver haloids, held in suspension with the emulsion, showed themselves in an exaggerated coarseness when it became a question of enlarging the pin-point photographs to the dignity of one-eighth of an inch, projecting them upon a screen, or viewing them through a binocular microscope. Each accession of size augmented the difficulty, and it was resolved to abandon that line of experiment, and to revolutionize the whole nature of the proceedings by discarding these small photographs, and substituting a series of very much larger impressions, affixed to the outer edge of a swiftly rotating wheel or disk, and supplied with a number of pins, so arranged as to project under the centre of each picture. On the rear of the disk, upon a stand, was placed a Geissler tube, connecting with an induction coil, the primary wire of which, operated by the pins, produced a rupture of the primary current, which, in its turn, through the medium of the secondary current, lighted up the Geissler tube at the precise moment when a picture crossed its range of view. This electrical discharge was performed in such an inappreciable fraction of time, the succession of pictures was so rapid, and the whole mechanism so nearly perfect, that the goal of the inventor seemed almost reached.

Then followed some experiments with drums, over which sheets of sensitized celluloid film were drawn, the edges being pressed into a narrow slot in the surface, similar in construction to the old tin-foil phonograph. A starting-and-stopping device very similar to the one now in use was also applied. The pictures were then taken spirally to the number of two hundred or so, but were limited in size, owing to the rotundity of surface, which brought only the centre of the picture into focus. The sheet of celluloid was then developed, fixed, etc., and placed upon a transparent drum, bristling at its outer edge with brass pins. When the drum was rapidly turned, these came in contact with the primary current of an induction coil, and each image was lighted up in the same manner as described in the previous disk experiment, with this difference only, that the inside of the drum was illuminated.

The next step was the adoption of a highly sensitized strip of celluloid half an inch wide; but this proving unsatisfactory, owing to inadequate size, one-inch pictures were substituted on a band one and a half inches wide, the additional width being required for the perforations on the outer edge. These perforations occur at close and regular intervals, in order to enable the teeth of a locking device to hold the film steady for nine-tenths of the one forty-sixth part of a second, when a shutter opens rapidly and admits a beam of light, causing an image or phase in the movement of the subject. The film is then jerked forward in the remaining one-tenth of the one forty-sixth part of a second, and held at rest while the shutter has again made its round, admitting another circle of light, and so on until forty-six impressions are taken a second, or 2760 a minute. This speed yields 165,600 pictures in an hour, an amount amply sufficient for an evening's entertainment, when unreeled before the eye. By connecting the two ends of the strip, and thus forming a continuous band, the pictures can be indefinitely multiplied. In this connection it is interesting to note that were the spasmodic

A SPANISH DANCER.

motions added up by themselves, exclusive of arrests, on the same principle that a train record is computed independent of stoppages, the incredible speed of twenty-six miles an hour would be shown.

The advantage of this system over a continuous band, and of a slotted shutter forging widely ahead of the film, would be this, that in that case only the fractional degree of light comprised in the $\frac{1}{2760}$ part of a second is allowed to penetrate to the film at a complete sacrifice of all details, whereas in the present system of stopping and starting, each picture gets one-hundredth part of a second's exposure, with a lens but slightly stopped down, time amply sufficient, as any photographer knows, for the attainment of excellent detail even in an ordinarily good light. It must be understood that only one camera is used for taking these strips, and not a battery of cameras, as in Mr. Muybridge's photographs of "the horse in motion."

The next step after making the negative band, is to form a positive or finished series of reproductions from the negative, which is passed through a machine for the purpose, in conjunction with a blank strip of film, which, after development and general treatment, is replaced in the kinetoscope or phono-kinetoscope, as the case may be. When a phonograph record has been taken simultaneously with such a strip, the two are started together by the use of a simple but effective device, and kept so all through, the phonographic record being in perfect accord with the strip. In this conjunction, the tiny holes with which the edge of the celluloid film is perforated correspond exactly with the phonographic record, and the several devices of the camera, such as the shifting of the film and the operations of the shutter, are so regulated as to keep pace with the indentation made by the stylus upon the phonographic wax cylinder, one motor serving as a source of common energy to camera and phonograph when they are electrically and mechanically linked together.

The establishment of harmonious relations between kinetoscope and phonograph was a harrowing task, and would have broken the spirit of inventors less inured to hardship and discouragement than Edison's veterans. The experiments have borne their legitimate fruit, and the most scrupulous nicety of adjustment has been achieved, with the resultant effects of realistic life, audibly and visually expressed.

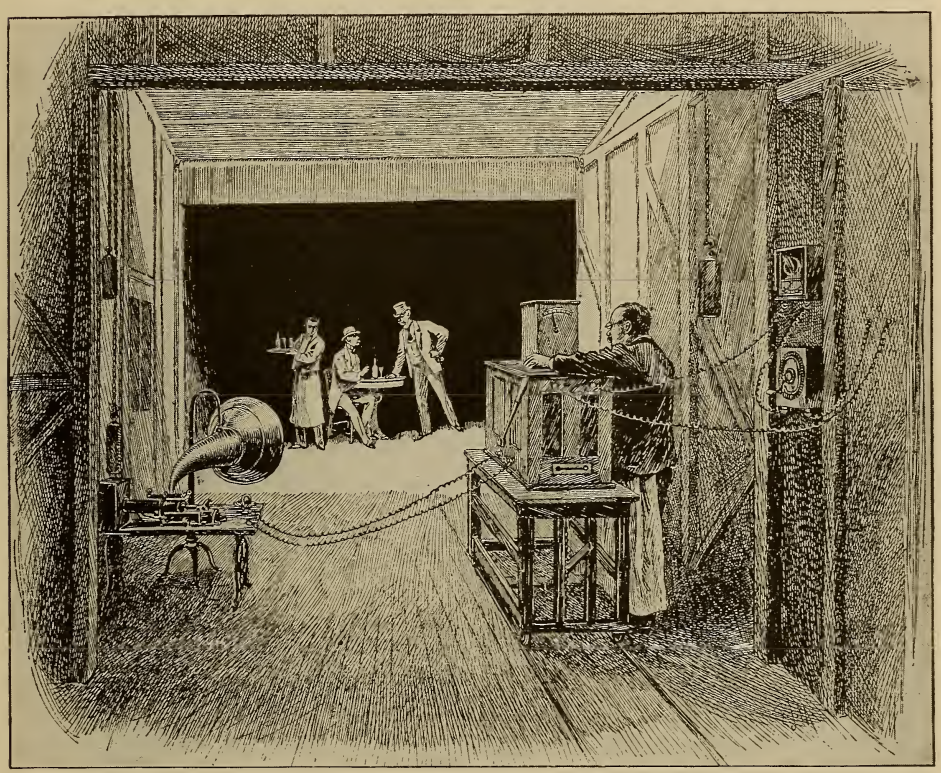
The process of "taking" is variously performed—by artificial light in the photographic department, or by daylight under the improved conditions of the new theatre, of which we shall speak. The actors, when more than one in number, are kept as close together as possible, and exposed either to the glare of the sun, to the blinding light of four parabolic magnesium lamps, or to the light of twenty arc lamps, provided with highly actinic carbons, supplied with powerful reflectors equal to about fifty thousand candle-power. This radiance is concentrated upon the performers while the kinetograph and phonograph are hard at work storing up records and impressions for future reproductions.

A popular and inexpensive adaptation of kinetoscopic methods is in the form of the well-known nickel-in-the-slot machine, consisting of a cabinet containing an electrical motor and batteries for operating the mechanism which acts as the impelling power to the film. The film is in the shape of an endless band from fifty to one hundred and fifty feet in length, which is passed through the field of a magnifying glass perpendicularly placed. The photographic impressions pass before the eye at the rate of forty-six per second, through the medium of a rotating, slotted disk, the slot exposing a picture at each revolution, and separating the fractional gradations of pose. Projected against a screen, or viewed through a magnifying glass, the pictures are eminently life-like, for the reason that the enlargement need not be more than ten times the original size. On exhibition evenings the projecting-room, which is situated in the upper story of the photo-

graphic department, is hung with black, in order to prevent any reflection from the circle of light emanating from the screen at the other end, the projector being placed behind a curtain, also of black, and provided with a single peep-hole for the accommodation of the lens. The effect of these sombre draperies, and the weird accompanying monotone

graphic displays, is conspicuous by its absence.

Nothing more vivid or more natural could be imagined than these breathing, audible forms with their tricks of familiar gesture and speech. The inconceivable swiftness of the photographic successions, and the exquisite synchronism of the phonographic attachment, have re-

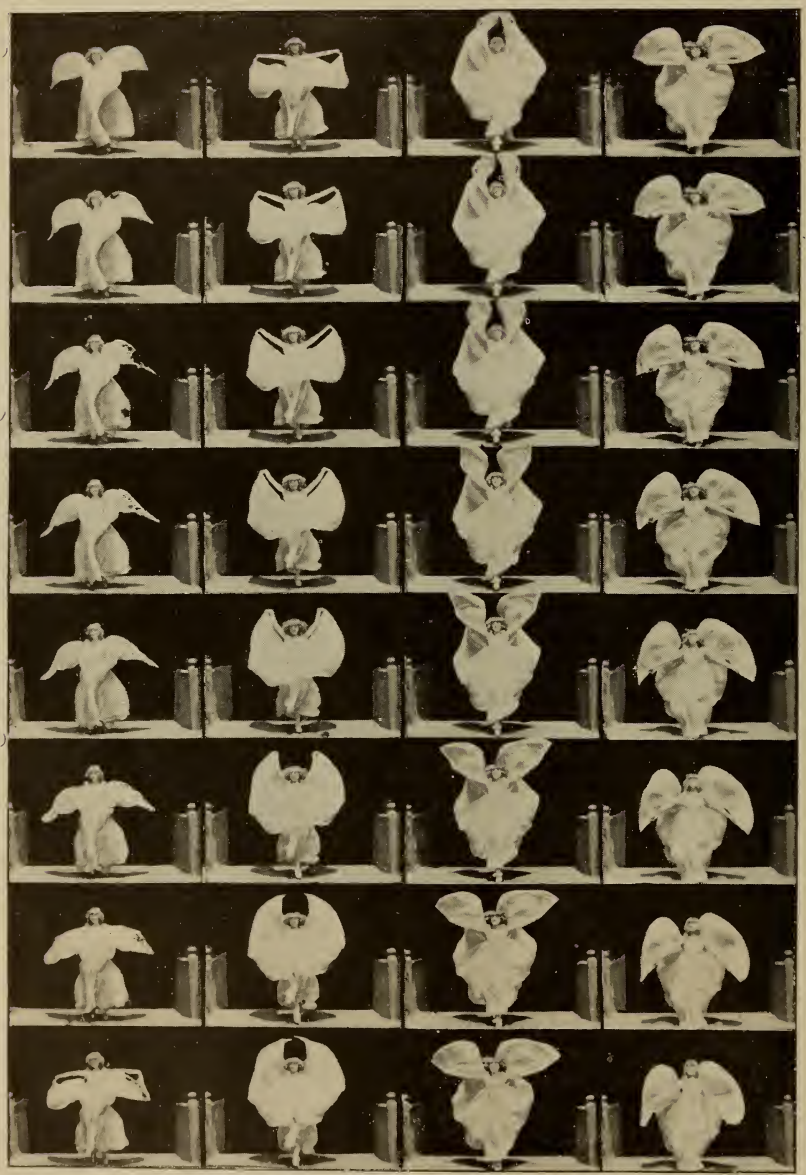


DRAWN BY E. J. MEEKER

INTERIOR OF THE KINETOGRAPHIC THEATRE.

of the electric motor attached to the projector, are horribly impressive, and one's sense of the supernatural is heightened when a figure suddenly springs into his path, acting and talking with a vigor which leaves him totally unprepared for its mysterious vanishing. Projected stereoscopically, the results are even more realistic, as those acquainted with that class of phenomena may imagine, and a pleasing rotundity is apparent, which, in ordinary photo-

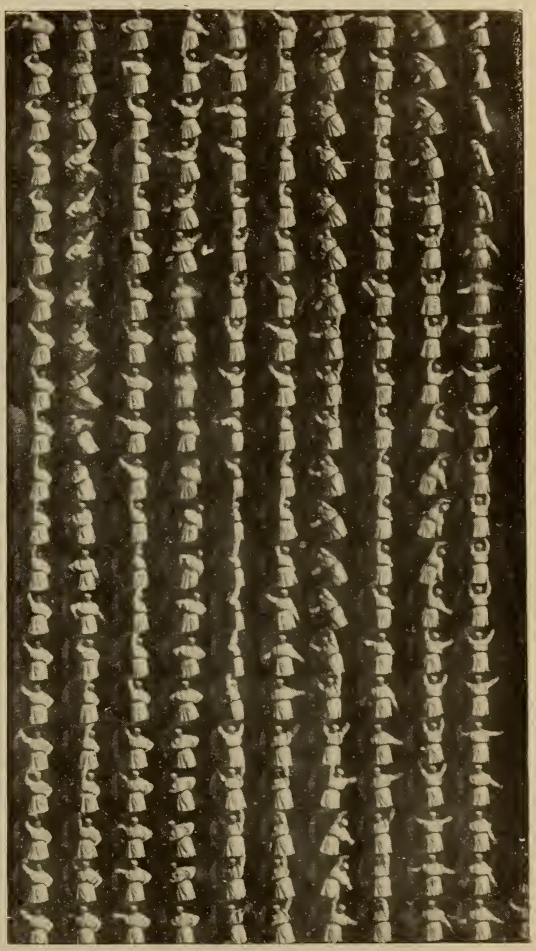
moved the last trace of automatic action, and the illusion is complete. The organ grinder's monkey jumps upon his shoulder to the accompaniment of a strain from "Norma." The rich tones of a tenor or a soprano is heard, set in their appropriate dramatic action; the blacksmith is seen swinging his ponderous hammer, exactly as in life, and the clang of the anvil keeps pace with his symmetrical movements; along with the rhythmical measures of the dancer



A SERPENTINE DANCE.

go her soft-sounding foot falls; the wrestlers and fencers ply their intricate game, guarding, parrying, attacking, thrusting, and throwing, while the quick flash of the eye, the tension of the mouth, the dilated nostrils, and the strong, deep breathing give evidence of the potentialities within.

The photographic rooms, with their singular completeness of appointment, have been the birthplace and nursery of this invention; and the more important processes connected in the preparation and development of the film, together with their mechanical and scientific devices, are still carried on in this department. The exigencies of natural lighting incident to the better "taking" of the subjects, and the lack of a suitable theatrical stage, however, necessitated the construction of a special building, which stands in the centre of that cluster of auxiliary houses which forms the suburbs of Edison's laboratory, and which is of so peculiar an appearance as to challenge the attention of the most superficial observer. It obeys no architectural rules, embraces no conventional materials and follows no accepted scene of color. Its shape is an irregular oblong, rising abruptly in the centre, at which point a movable roof is attached, which is easily raised or lowered at the will of a single manipulator. Its color is a grim and forbidding black, enlivened by the dull lustre of many hundred metallic points; its material is paper, covered with pitch and profusely studded with tin nails. With its flapping side-like roof and ebon hue, it has a weird and semi-nautical appearance, and the uncanny effect is not lessened when, on an imperceptible signal, the great building swings slowly around upon a graphited centre, presenting any given angle to the rays of the sun, and rendering the operators independent of diurnal variations. The movable principle of this building is identical with that of our river swinging bridges, the ends being suspended by iron rods from raised centre posts. This building is known as the Kinetographic Theatre, otherwise the "Black Maria." Entering, we are confronted by a system of



AN EARLY KINETOSCOPIC EXPERIMENT.

lights and shades so sharply differentiated as to pain the eye, accustomed to the uniform radiance of the outer air.

As we peer into the illusive depths we seem transported to one of those cheerful banqueting halls of old, where the feudal chief made merry with human terrors, draping the walls with portentous black, and thoughtfully providing

THE RECORD OF A SNEEZE.

THE RECORD OF A SNEEZE.

a set of coffins for the accommodation of his guests. And what is this mysterious recess at the other extremity, sharply outlined against the dazzling radiance of the middle ground and steeped in an angry crimson hue? Are these inquisitorial dungeons, and is that lurid glare the advance guard of the awful Question? Is that gentle persuasive in process of administration, and do these half-guessed recesses conceal the hellish paraphernalia of rack and screw, glowing iron and crushing stone? Has the doom of ages overtaken our wizard at last, and is he expiating, with twisted limb and scorching flesh, the treasures of his unlawful wisdom? Ah! me, that the prosaic truth must be told! No dungeons are these, thrilling with awful possibilities, but simply a building for the better "taking" of kinetoscopic subjects. On the platform stand the wrestlers, pantomimists, dancers and jugglers, whose motions it is destined to immortalize. Against the nether gloom their figures stand out with the sharp contrast of alabaster basso-relievos on an ebony ground, furnishing a satisfactory explanation for the singular distinctness of the kinetoscopic strips. The lurid cell, at the other end, resolves itself into a compartment for changing the films from the dark box to the kinetoscopic camera, the apparatus being run backward over a track leading from the black tunnel at the rear of the stage to this room, after which the door is shut and the films are renewed for a fresh subject.

We have been sensible for some time of a disturbance in the ground beneath our feet, and are now aware that the building is slowly and noiselessly rotating on an axis, bringing into our range of vision the glory of the sun rays westering to their close. Again we are reminded of that indissoluble chain of ideas which links the past with the present, and into the commonplace of existing facts come memories of that chamber in the golden house of Nero, so arranged that "by means of skillfully planned machinery it moved on its axis, thus following the motion of the heavens, so that the sun did not appear to change in position, but only to descend and ascend perpendicularly."

The *dramatis personæ* of the kinetographic stage are recruited from every characteristic section of social, artistic and industrial life, and from many a phase of animal existence. One day chronicled the engagement of a troupe of trained bears and their Hungarian leaders. The bears were divided between surly discontent and a comfortable desire to follow the bent of their own inclinations. It was only after much persuasion that they could be induced to subserve the interests of science. One furry monster waddled up a telegraph pole, to the soliloquy of his own indignant growls; another settled himself comfortably in a deep arm-chair, with the air of a post graduate in social science; a third rose solemnly on his hind legs and described the measures of some dance, to the weird strain of his keeper's music. Another licked his master's swarthy face, in deprecation of the invitation to move, while another accepted his keeper's challenge, and engaged with him in a wrestling match, struggling, hugging and rolling on the ground.

Of human subjects we have a superfluity, although the utmost discrimination is essential in the selection of themes. The records embrace pugilistic encounters, trapeze and cane exercises, dancing, wrestling, fencing, singing, the playing of instruments, speechmaking, the motions involved in the different crafts, horse-shoeing, equestrianism, gardening and many others.

We have yet to speak of the microscopic subjects, a class of especial interest, as lying outside of the unaided vision of man. In the treatment of these infinitesimal types, much difficulty was experienced in obtaining a perfect adjustment so as to reproduce the breathing of insects, the circulation of blood in a frog's legs and other attenuated processes of nature. The enlargement of animalculæ in a drop of stagnant water proved a most exacting task, but by the aid of a powerful limelight, concentrated on the water, by the

CAICEDO, THE KING OF ROPE DANCERS.

interposition of alum cells for the interception of most of the heat rays, and by the use of a quick shutter and kindred contrivances, the obstacles were overcome, and the final results were such as fully to compensate for the expenditure of time and trouble.

We will suppose that the operator has at last been successful in imprisoning the tricksy water-goblins on the sensitive film, in developing the positive strip, and placing it in the projector. A series of inch-large shapes then springs into view, magnified stereoptically to nearly three feet each, gruesome beyond power of expression, and exhibiting an indescribable celerity and rage. Monsters close upon one another in a blind and indiscriminate attack, limbs are dismembered, gory globules are tapped, whole battalions disappear from view. Before the ruthless completeness of these martial tactics the Kilkenny cats fade into insignificance. A curious feature of the performance is the passing of these creatures in and out of focus, appearing some times as huge and distorted shadows, then springing into the reality of their own size and proportions.

Hitherto we have limited ourselves to the delineation of detached subjects, but we shall now touch very briefly upon one of our most ambitious schemes, of which these scattered impersonations are but the heralds. Preparations have long been on foot to extend the number of the actors and to increase the stage facilities, with a view to the presentation of an entire play, set in its appropriate frame.

This line of thought may be indefinitely pursued, with application to any given phase of outdoor or indoor life which it is desired to reproduce. Our methods point to ultimate success, and every day adds to the security and the celerity of the undertaking. No scene, however animated and extensive, but will eventually be within reproductive power. Martial evolutions, naval exercises, processions and countless kindred exhibitions will be recorded for the leisurely gratification of those who are debarred from attendance, or who desire to recall them. The invalid, the isolated country recluse, and the harassed business man can indulge in needed recreation, without undue expenditure, without fear of weather, and without the sacrifice of health or important engagements. Not only our own resources but those of the entire world will be at our command. The advantages to students and historians will be immeasurable. Instead of dry and misleading accounts, tinged with the exaggerations of the chroniclers' minds, our archives will be enriched by the vitalized pictures of great national scenes, instinct with all the glowing personalities which characterized them.

# MANUFACTURING MACHINERY—OR BUILDING IT.

*By Oberlin Smith.*

IN Adam Smith's well-known illustration of the economy attained by the principle of division of labor, as applied to the art of pin-making, written over a century ago, he estimates the daily product of one artisan as about five hundred pins. He compares this work with a product of one pin per day, if made in the old-fashioned way, the various operations all being performed by one person, without special training or appliances, presumably including all the work from the crude pig metal onward. Had he lived to examine modern methods he would doubtless have introduced a new principle into his political economy, that of the multiplication of brain work. By its application he could have shown, perhaps, another five-hundred-fold increase in the per-man-per-day output of that very useful implement, the common pin. In the wonderful automatic machines used for the production of this and other small articles, he would have seen also the embodiment of still another important principle, which is so large a factor in our modern industrial life, namely, the controlled distribution of mechanical power. By this I mean the application of force in a machine, just where, when and how it is required.

In the construction of machinery any or all of the three principles above mentioned may be carried out to a greater or less extent, usually dependent upon how many individual articles of one kind are required to be made at one time. Where they are all so applied we have an example of manufacturing proper, in contra distinction to mere making or building, as implied in the title of this article.

The cheap and systematic manufacturing of simple articles of daily use, such as the pins of Adam Smith's time and earlier, was naturally developed as fast as current civilization enabled and demanded the cheapening of its implements for the convenience and happiness of mankind. The tools or machines, however, with which these articles were made, were themselves built "piece meal," as it were, usually being designed by a gradual process of evolution. This went on for a long time, and is still going on, in regard to the great majority of intricate machines.

Within a comparatively short time, however, measured chiefly by the latter half of this century, wonderful cheapening processes have been applied to the production of certain machines by the thousands and tens of thousands whose function, in their turn, is the production of the various articles in common use by millions and tens of millions. Familiar examples of this are seen in the modern American system of manufacturing clocks and watches, whose product, so to speak, is hours, minutes and seconds; sewing machines, whose product is clothing; guns and pistols, with a product of defunct soldiers, exterminated wild animals and mutilated small boys; mowers and reapers, producing hay and grain; together with a great variety of other improved devices whose number and ingenuity is constantly increasing.

There is not space in this article to dwell in detail upon the character and the enormous importance to our civilization of this great system of manufacture that has almost imperceptibly been engrafted upon our modern existence and which has so wonderfully cheapened

the necessaries, and often luxuries, of our lives. Recurring to the three before-mentioned principles involved in the rapid production in question, division of labor is not the least important. This is, of course, applicable only to cases where similar articles are made in large quantities, as such a division would only add to the cost of a single article, or a small "batch" thereof. The principle, however, is not new, as it was undoubtedly carried out to a greater or less degree of perfection among the pyramid, temple and aqueduct builders of ancient times. The third principle mentioned, of the exactly controlled distribution of force, which has, perhaps, reached its highest development in some of the modern automatic machinery, is also of hoary age in certain of its applications, as is witnessed by the water-wheels, pumping apparatus and other devices of centuries long past.

Power thus controlled, even in an intricate machine, need not necessarily be derived from the so-called mechanical forces, operating such motors as steam engines, water-wheels, etc., as muscular force derived from men, horses, or other animals and applied to a prime distributor, as a rotating shaft, could not, if properly governed, be distinguished from any other prime-mover. When distributed, however, among the various grippers and cutters, grinders and swedgers of a pin machine, for instance, each steel lever, finger and pawl moving in exact time and with exactly measured force and distance in relation to all its fellows, any force derived from the prime-mover becomes strictly mechanical and can be applied with a precision and rapidity unattainable by the fingers of workmen, no matter how skillful. In heavy work, however, where powerful forces are required, it would in some cases be impossible to substitute for the steam engine muscular energy in the space required for its application. An instance of this may be seen in the driving of a great steamship at twenty-five miles an hour, or a Pullman train at seventy-five.

We see, therefore, in modern manufacturing the application, to a more or less degree, of properly divided human labor and of properly controlled mechanical force, whencesoever derived, as two essential principles which, in some form or other, are almost as old as the world's history. The second principle before-mentioned, the one tending to upset all of Adam Smith's calculations in regard to pin making, that of the multiplication of brain work, as I have called it for want of a better and briefer name, seems, however, to be of comparatively modern origin, except possibly in the Chinese Empire. The most notable example of this principle is shown in the art of printing, where the brain work used to prepare and arrange the types for printing a copy of a given manuscript is duplicated a thousand or a million-fold by means of cheap labor, which needs absolutely none of the original brain power, but only the necessary experience for the routine management of the apparatus. The same principle is, of course, used in the production of pictures of all sorts, from chromo-lithographs down, "chromos" being mentioned first, not because of their necessarily artistic merits, but because they require, with their many colors, a more complex process than do any prints embodying merely blacks and whites.

Numerous other examples of this principle can be found in various branches of industrial life. The most modern and most important use of it is exemplified in the "special tools," so-called, which have been the most vital factors in the cheap, accurate and uniform productions of the various machines mentioned in the former paragraphs. These special tools consist chiefly of gauges, templets, cradles and jigs. A gauge may obviously be made in many forms, its function in any case being to measure the size of some part of the object to which it is applied, either externally or internally, or to determine the distance apart between certain holes, flanges, or other characteristic features. It usually is of fixed dimensions and serves to identify and keep standardized measurements and

locations which are determined in the first place by templets or jigs.

The word *templet* is not very well defined, but is usually applied to a tool which not only partakes somewhat of the nature of a gauge, but which locates certain holes and other details of construction by directing, scribing or other marking tools which are slid against the internal or external edges of said templet. The tool itself usually consists of a thin plate of metal, having, in some cases, certain lugs or pins projecting from it wherewith to locate it upon the work to be templeted; and having, furthermore, various holes, notches and other working edges which serve as guides for a scribing tool. The use of a templet does not locate holes, etc., with extreme accuracy, because of errors afterward occurring with drilling or other cutting tools by not strictly following the lines which are scribed by the templet. It often answers a sufficiently accurate purpose, however, and will enable a group of holes to be quickly marked out upon any number of surfaces to which it may be applied, these markings all being in duplicate. A familiar application of the templet principle is seen in stencils of various kinds, a paint brush being substituted for a scriber. In this form a templet can scarcely be called a modern device.

The term *cradle* is usually applied to a tool in which a number of similar pieces of irregular-shaped work can be successively inserted and brought to a given location, being secured by proper clamping devices. This cradle usually has a base which is exteriorly flat or otherwise adapted to fit the machine, as a planer or drill-press, in which the work is to be treated, its function being to form a false base for work not in itself provided with a true and flat bottom, or group of legs, upon which it can firmly rest.

The tool familiarly known as a *jig* is by far the most important in its nature and functions of all the special-tools in question. It is usually employed for the accurate locating of a hole, or a group of holes, to be drilled or bored in the piece of metal or other material to be operated upon—technically known as "the work." It is sometimes provided, however, with locating edges for guiding certain tools which produce planes and other definite surfaces, as well as cylindrical holes. In its simplest form it consists of a flat plate of metal which can be clamped upon, or otherwise secured to, the upper surface of the work, being perforated with round holes, through, and guided by which, a vertical revolving drilling tool is passed, to drill the required holes. Sometimes this jig is located in reference to the work simply by the eye; but more generally it is guided by flanges, pins or other projections, partly or wholly surrounding the work, and either fitting it tightly, or being brought to a fit by movable jaws or other devices. When such a jig is intended to locate a group of holes, either of the same or different sizes, it is, of course, perforated to agree therewith. Such a tool as this is obviously suited for lying upon a true horizontal surface, with its pins or flanges projecting below, just as the lid of a pasteboard box might be slipped over the broad surface of a brick, and is, moreover, generally used on work having a flat base of its own, the brick being an analogy therefor. Obviously, work having such a plane surface for a base, or provided with a false base of some sort, can be laid upon the horizontal table of a vertical drilling machine and quickly slid by hand, if not too heavy, to the different positions required for the various holes which are to be drilled, the jig itself determining the location of the combined structure of work and jig, by allowing the drill to enter each of its holes successively.

A more complex form of jig is adapted not only for drilling a group of parallel holes as above described, but other holes in any of the other sides of the work, and these at any desired angle with, as well as distance from, each other. In such case, if the work is cubical or of any rectangular form, after the fashion of our supposititious brick, it is evident that its jig may be in the shape of a rectangular box which,

with its lid, will completely enclose it, that is, providing all of its six sides are to be operated upon. The brick, when thus enclosed, would have the six planes bounding the jig for its temporary bases, and could evidently thus be perforated with a large number of holes, all agreeing with those in the jig, and all of which would be located in exactly the same relative positions as would those in the thousand or million other bricks which might be successively inserted in the jig. Strictly speaking, this is true only when assuming that the jig holes do not wear larger, or the drills wear smaller, so as to be appreciably loose in fitting each other. In practice such looseness is, of course, cumulative, and is allowed to produce its inevitable errors up to a certain limit of accuracy which is regulated by more or less frequent inspections with master gauges which are used to keep the jig and boring tools up to a certain standard. These master gauges are usually made with extreme care and accuracy, and when not in use are kept securely locked up, as a safeguard against accidents or malicious tampering. In some cases grand master gauges are provided, preserved with still more care, to test the master gauges.

It often, and indeed most frequently, happens that work is not cubical in its general form, being sometimes extremely irregular—as, for instance, in the case of a frame of a sewing machine. Furthermore, holes and other surfaces are often desired at other angles with each other than those of ninety degrees, as was assumed for our imaginary brick. In such cases it is only necessary that some exterior flat base be provided upon the side of the jig opposite to any given hole to be drilled, the plane of said base being perpendicular to the axis of such hole. In cases where a horizontal drilling tool is used, with its axis parallel to the bed of the drilling machine, a jig is, of course, constructed to suit, having its temporary base arranged to rest upon the machine bed in question.

In actual practice, a jig for drilling a few dozen holes, some of them perhaps being of two or three different sizes, or countersunk at their ends, or tapped with a screw-thread all or a part of their length, consists of an accurately made iron box, sometimes with partly open sides, having perhaps a hinged lid, which, when closed down, clamps the work securely in place, with the bearing points against it at certain definite locations which will give the best average position, even though the rough surfaces of the casting are accidentally somewhat varied in position and form. To suit these variations, the clamping devices are adjustable. This box is perforated upon its various sides with the proper number of holes, each of which is bushed with a hardened steel bushing accurately ground to size. These guide the drills and other boring tools until worn loose, when they are cheaply taken out and replaced with new bushings, thus enabling the jig proper to last an indefinite time and yet maintain its original accuracy.

With such a tool sliding freely upon the truly planed horizontal bed of a gang drilling machine, above which are constantly revolving a number of properly made drills, each capable of being fed down to a fixed position, and no farther, by an accurately adjusted stop gauge (or, as in some cases, with the drill vertically fixed and the bed fed upward toward it) a boy or other low-priced operative can, with great rapidity, produce a group of holes, which are located with practically the same accuracy as are those in the jig. Furthermore, he can do it a thousand or ten thousand or ten million times with the same uniformity and certainty that he can once. He is thus, without appreciable brain labor, doing as accurate and almost infinitely quicker work than did the educated engineer who designed the jig and the drilling machine, and the careful high-priced machinist who made them, such a jig having cost perhaps hundreds of dollars, and the locating and drilling of the holes in it having occupied hundreds of hours, the measuring often being done in thousandths and even ten-thousandths of an

inch. In this comparatively simple tool, therefore, we see exemplified the same grand and universal principle of duplicating and multiplying valuable and tedious brain work that is seen in that epitome of civilization, the printing press. The process of thus multiplying certain pieces of work by jig-drilling them is to the hand-drilling of one such piece (which it would be almost as much trouble to drill as the jig itself) as is the printing of a large edition of a book to the elaborate writing of one copy with a pen, after the fashion of the Middle Ages. There are, of course, many other processes other than those mentioned which have been greatly cheapened by a high degree of specialization. Among these are special forms of turning, planing, milling, etc. Hole-making seems, however, to take the lead, because, perhaps, by its means chiefly the individual members of a structure are attached to each other.

Mention has already been made of the general character of the machinery produced in this nineteenth century fashion. Such processes are truly manufacturing. They are, however, evidently not suited to the construction of steamship hulls, bridges and large sizes of engines, pumps, lathes, planers, etc., simply because these articles are usually built one at a time, or at any rate in very small batches. Obviously, the enormous expense of special tools for producing them would, in this age of the world, even if they were standardized enough to create a large demand, prove entirely prohibitory. We must, therefore, in this generation at least, expect to see all such machinery made in the old-fashioned way, that is, simply built, and not manufactured. A partial exception to this occurs in connection with certain detailed members of the structures in question, as, for instance, many of the beams, link-bars, pins, etc., in a bridge, or the bolts and nuts in an engine, which members can often be made in duplicate, with the advantage of using special tools.

Between the large structures mentioned, which, on the whole, are merely built, and in quantities of but one or two at a time, and the small machinery before alluded to, which can be made in lots or batches of from a hundred to a million at a time, there is a large class of medium sized machines, such as small lathes, planers and other machine tools, high-speed engines, dynamos, steam pumps, presses and shears, etc., etc., which are made in batches of from five to fifty at once, and to which some of the cheapening processes in question can be applied. In building such constructions the wise machine-shop owner will, and often does, use the principle of division of labor, to a greater or less extent, according somewhat to the number of his employees. He also in these days uses the controlled power principle in almost all his work, as the admirable general tools now in use in most shops leave little to be desired upon this point, from the operations of planing, turning, boring, etc., down to the rapid handling of heavy pieces by electrical and other quick-moving cranes. These, happily, are now becoming fashionable.

In the vital principle of multiplying brain-power, as exemplified in the jig-work, etc., shop-owners still fall a good deal short of the high standard which they might reach, greatly to the benefit of themselves and their customers. The main object of this article, though the reader, in perusing the long preamble, may hardly have suspected it, is to urge the importance of this intermediate class of machinery, which is usually built in comparatively small batches, being manufactured, rather than thus built, by means of the obviously sensible and enormously money-saving tools, consisting chiefly of gauges, cradles and jigs, which have been described in the preceding paragraphs.

It must be remembered also that the cheapening of a piece of work in the actual formation is not the only advantage of making it with a jig, rather than by hand. The incidental advantage of uniformity in all parts, which enables machines to be assembled with almost infinitely less fitting, and which, more-

over, enables them to be afterward repaired by the substitution for broken and worn pieces of duplicates from the same maker, has proved of tremendous, and at first unthought-of, advantage, this uniformity being indeed the leading characteristic of what is frequently known as the American interchangeable system of manufacturing. Of course, in the small-sized batches in question, averaging perhaps not more than ten made at one time, we cannot expect the great saving of cost obtained in an article like a sewing-machine, which is now produced complete and of first-class quality for less than ten dollars, against a cost of perhaps twenty times as much were it made singly, but with good tools and workmen, in an ordinary machine-shop.

The reverse of the above picture should obviously be shown, and this would teach that much caution must be observed before going too extensively and expensively into the procuring of special tools for the manufacturing of any machine regarding which there is any doubt whatever as to commercial demand, in reasonably large quantities. Great care should be taken not to design jigs and other such tools for any article which is not thoroughly standardized and really ready for the market, not only mechanically but commercially. In average shop practice it is by far too often the case that a machine will seem to be all right and ready for manufacturing, when in reality it is not entirely out of the experimental stage. Under such conditions important changes are very likely to be required, either as the result of a salesman finding out that customers think they want something changed; or, more likely, from the maker finding out that something must be altered to suit the severe requirements pertaining to actual operation, month in and month out—such hard work having shown imperfections which were not developed in a mere shop trial, but which must be duly remedied. In still other cases the machine itself may run well enough and suit its purchaser, but the maker may find that something can be so improved in action and simplified in construction as to make the machine enough better or cheaper, or both, to justify him in wholly or partially re-designing it. Then, again, a competitor's machine may appear with additional speed or more comprehensive functions which must be met—and beaten.

In all the cases mentioned there is danger that a set of special tools, or a part thereof, will have to be thrown away before they have been used long enough to anywhere near pay for themselves. Much circumspection is, therefore, necessary in looking carefully at both sides of the question before making rash outlays for tools which, when really desirable, are of such extreme value, but which, on the contrary, are worth something less than a cent a pound when not exactly adapted to their environment. In this respect they are vastly different from general machine tools, which, when out of use for one purpose, can easily be turned to account for something else, and which, moreover, have usually a definite market value. Jigs, but for the tender mercies of the junk man, have, under such circumstances, a valuation absolutely *nil*.

# JOHN ERICSSON, THE ENGINEER.

JULY 31, 1803—MARCH 8, 1889.

*By William Conant Church.*

(Continued from page 21.)

JOHN ERICSSON'S career covers the entire period within which civil engineering has been recognized as a distinct profession—if we are to date from the organization in 1818 of the English Institution of Civil Engineers. During the fifty years preceding this date the modern era of engineering had been gradually shaping itself out of the labors of Smeaton, originally a maker of mathematical instruments; Brindley, a millwright; Telford, a stone-mason; Fairbairn and Stephenson, Newcastle collierymen, and others like them, uneducated or self-taught. In professional equipment Ericsson was superior to any of these, and, when he landed in England, in 1826, was prepared to enter the lists against the ablest of his contemporaries. His youthful training on the Götha Canal, his intercourse there with men familiar with English methods, and his intelligent study of the best models had admirably fitted him for the work before him. He understood English well, he was full of energy and enthusiasm, he had an inexhaustible fund of vital force and a rare capacity for continuous work. But his strength in natural endowment was at the same time his weakness, so far as the advancement of his personal fortunes was concerned. His inventive fecundity, the rapidity of his mental processes, the readiness with which his imagination transported him into new regions of industrial development made it difficult for him to realize that others must follow him by laborious steps, and that isolation in inventive experience is fatal to success in a business sense.

Before he had been two years in England, before his garments had fairly lost their Swedish cut or his speech the Norrland accent, Ericsson had added at least seven inventions to a list which was destined to grow so rapidly. In one of these, a machine for compressing air, patented in 1828, his friend and countryman Count von Rosen invested £10,000. It was employed to convey power to the pumps engaged in clearing of water a Cornish tin mine lying off the shore, and was apparently the earliest example of the use of this mechanical expedient. In 1828 also Ericsson patented a steam boiler, constructed on the principle of artificial draught, upon which all rapid locomotion depends. At this time Sir John Ross was planning his second expedition to the Polar seas. He ordered an engine for his vessel, the Victory, from the firm of which Ericsson was now a member, known as Braithwaite & Ericsson. Not wishing to reveal the purpose of his voyage, Ross allowed it to be understood that it was a naval vessel. The new engine was put into her, and a "surface-condenser," or the apparatus now in common use for condensing the steam from the engine by passing it, in closed pipes, through cold water and returning it to the boiler, to be used over and over again in a continuous circuit.

An important branch of Braithwaite's business was the construction of refrigerators and coolers for the mammoth

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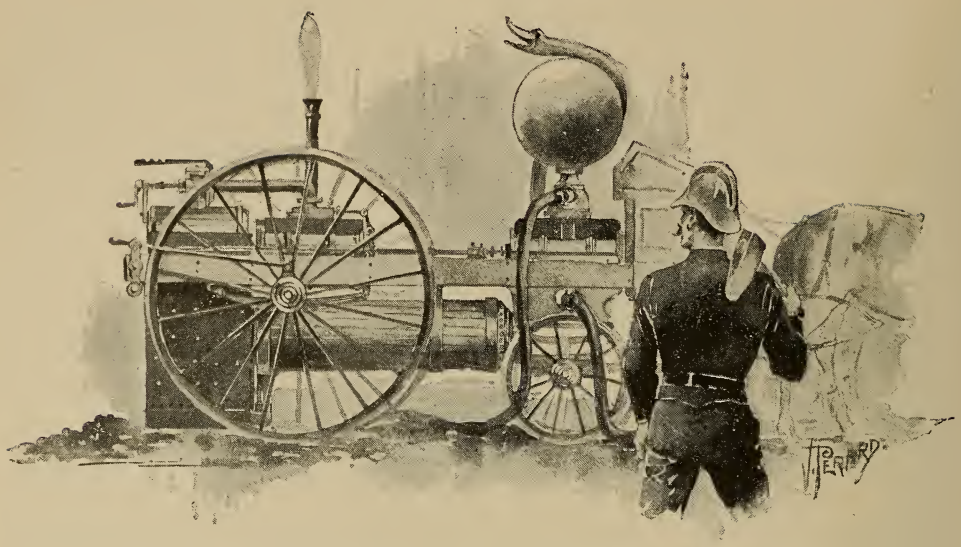


STEAM FIRE ENGINE AWARDED A PRIZE BY THE AMERICAN INSTITUTE, 1840.

breweries and distilleries of London, and it was experience with these that suggested the idea of adapting the same machinery to steam vessels. The plan, then entirely novel, of putting the engine below the water-line, was adopted in the Victory, and other devices, since common, were experimented with in her. Compactness in marine engines was, from the first, one of Ericsson's hobbies, but in this case he made a mistake. Greatly chagrined when he discovered the nature of the service for which the Victory was intended, he warned Captain Ross, in heated language, of the consequences of his disingenuousness. Features which afterward proved so successful in naval construction were out of place in a vessel intended for Arctic voyaging, and the engine was tumbled overboard as soon as the Victory got into the ice, to furnish proof to some post-glacial age that the Esquimaux were acquainted with steam engineering.

On his return from an unsuccessful voyage, after expending nearly one hundred thousand dollars of his patron's money, Sir John charged his failure to the unlucky engine. This was too much for Ericsson, who seldom found use for the soft answer that turneth away wrath when stung by a sense of injustice. A sharp controversy followed, and an encounter between the British naval officer and the ex-captain of the Swedish army was in prospect. Mr. Felix Booth, late High Sheriff of London, who had fitted out the Ross expedition, finally interfered and bloodshed was prevented.

The methods of extinguishing fires in London at this time were of the most primitive sort, and conflagrations were numerous and disastrous. The city had thrice been nearly destroyed. Drury Lane and Astley's Theatre had been twice burned; Covent Garden, the Italian Opera House, and Surrey, each once. The fire engines in use were provided by the several parishes into which London was divided and their inefficiency was notorious. Dickens describes an engine seen by him on the occasion of a fire, coming up "in gallant style—three miles and a-half an hour at least"—but so inefficiently worked when it arrived on the ground, "that eighteen boys and men had exhausted themselves in pumping for twenty minutes without producing the slightest effect." This was uncommon speed, for a mile and a-half an hour was the best gait of the broken-down

old fellows from the work-house who ordinarily manned the engines.

Ericsson sought to remedy this condition of things by inventing a steam fire engine. An experimental engine, placed on a rude carriage, was built in 1828. This was followed by four completed engines, mounted on springs, so as to run over the pavements easily. a starring tour through France and Russia, where it worked with perfect success. The Liverpool engine was in constant use, both for pumping water in large quantities, and for extinguishing fires, and the success of the Prussian engine—employed in protecting the public buildings of the capital—led to the bestowing of an honorary mem-

ERICSSON ON HIS ARRIVAL IN ENGLAND, AGED TWENTY-THREE.

One was employed in London, another went to the Liverpool Docks, and a third was ordered by the King of Prussia. The fourth was an experimental engine, built in 1833, on a new plan. The London engine proved its efficiency by extinguishing a fire at the Argyle Rooms when the hand engines were frozen up. It was then borrowed by Barclay & Co., after a fire which destroyed their brewery, and kept steadily at work for a month in emptying their vats of beer. It next went on bership in the Berlin Institute upon its manufacturer.

This was the end of Messrs. Braithwaite & Ericsson's attempts to substitute steam for hand-power in extinguishing fires. The very completeness of their success was their ruin. The most violent prejudices were aroused; the hose of the engine they had sent out at their own expense was cut by the jealous firemen; they were annoyed in every way; and the parish authorities who ruled London would have nothing

to do with an engine that consumed so much water.

"Mashallah!" exclaimed the Pasha, when a Yankee hand engine was first exhibited to him; "very good, but it will require a sea to supply it with water. It won't do for us, for there is no sea in the middle of Constantinople." There was no sea in the heart of London, and it was further urged that so much water "might be injudiciously applied." The firemen were then accustomed to supply their engines by digging a hole in the middle of the street, to collect the water, and they never had enough to do any harm. The same objection was made to the steam fire engine for which the Mechanics' Institute of New York, in 1840, awarded to Ericsson the prize offered for the best model of such a machine. There is on record a report by the Chief of the New York Fire Department declaring that steam fire engines would do more damage with water than could possibly be done by fire. A generation passed before the London authorities were ready for the steam fire engine. Then, in 1860, they adopted one, a machine so defective that they replaced it, after a trial of ten months, with another bearing a closer resemblance to the original invention.

While he was still at work upon his fire engine Ericsson found opportunity to apply in another direction the experience acquired in its construction. During the century preceding his transfer to England £220,000,000—a sum equivalent to our present National debt—had been expended in constructing twenty thousand miles of English turnpikes, so as to increase the possibilities of land carriage. Advance in this direction had reached its limit. Light vehicles, mounted on springs and speeding over the perfect highways of Macadam, had gradually replaced the pack horses and the rude carriages of a hundred years before. Great attention had been paid to improving the breed of carriage horses, and a speed of as much as ten miles an hour was familiar to passengers by the stage coaches. Such rapid traveling was considered highly deleterious, and when Lord Campbell first made the journey of two nights and three days from Edinburgh to London, whither he went to seek his fortune in 1798, his anxious family were alarmed with stories of those who had died of brain affections after journeying with a celerity so dangerous. The still more alarming speed of sixteen miles an hour was attained for a short distance with the Shrewsbury coaches over the exceptional route between Cheltenham and Tewkesbury. Beyond this, progress was impossible, for the limit of muscle-power was reached.

Various unsuccessful attempts had been made to apply steam power to traction upon the ordinary highways, but the demand for improvement in the transportation of passengers does not appear to have been active. The needs of the growing internal commerce of Great Britain were more urgent. Steam had saved her from the disaster impending when her mines had been excavated below the limits of economical mining by hand-power. It was now looked to as a means of relief from the further danger that commercial stagnation might result from inadequate means of transportation. The suggestion of a coming revolution was found in the system of tramways, employed at the Newcastle collieries for transporting coal for short distances from the mouths of the pits. George Stephenson, who had here gained his experience as an engine driver, was fighting the battle for railroads against Philistine England. Ponderous review logic and sparkling newspaper wit were devoted to ridiculing his claim that freight might be conveyed at a speed in excess of the ordinary passenger limit of ten miles an hour, and doleful prophecies were indulged in as to the results to follow the adoption of his revolutionary projects. Stephenson's chief purpose was the conveyance of freight. Even he does not appear to have dreamed of the effect upon passenger travel of his invoking "the aid of the devil, in the form of a locomotive, sitting as postilion on the forehorse," as a parliamentary

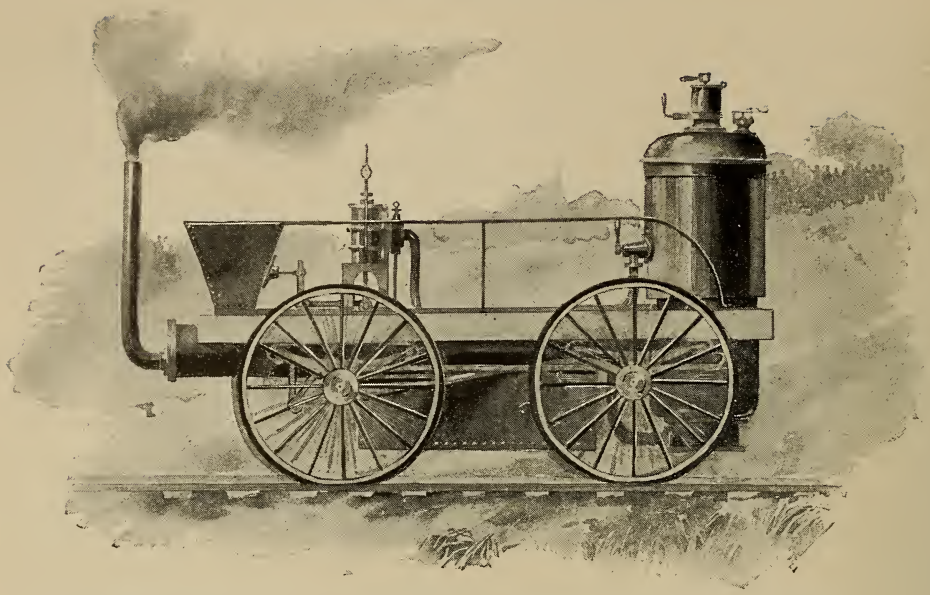
advocate described it. Sir Astley Cooper complained that the railroad would "destroy the noblesse." Dr. Arnold, of Rugby, for the same reason, rejoiced, declaring that feudality was gone forever, and that it was a blessing to think that any one evil was really extinct. The aristocratic few were no longer to have the pleasure of throwing their dust in the faces of the humble thousands, trudging wearily along the public highways. Comfort and speed, such as the lordliest had never dreamed of, were to be brought within the reach of all. "To move the rich needed only a four-horse coach, running in an agony of ten miles an hour; but to move the poor required cars before which those of the triumphing Cæsars must pale their ineffectual competition."

In 1829 Stephenson had secured his railroad uniting Liverpool with Manchester, and had narrowed the discussion between himself and his opponents to determining whether stationary engines or locomotives should be used. In the decision of this question, as the result showed, was involved the future of railroad development. It was finally decided to test the matter by offering a prize of £500 sterling for the best locomotive answering certain requirements. Five months were allowed for preparation. The advertisement inviting the competition did not reach the eye of Ericsson, busied at this time with his fire engine. He could have had no better training for locomotive construction than this was giving him; but, unfortunately, only seven weeks of the twenty-one remained, when an incidental allusion in the letter of a friend from Liverpool for the first time informed him of the coming contest. Stephenson was the engineer of the railroad offering the prize; he had made a special study of locomotives, and even before Ericsson commenced work had, with the aid of his son Robert, completed his trial engine, and was sifting it of its defects by testing it on a track controlled by him. Ericsson had to design and construct his locomotive in the utmost haste, and to hurry it to the track straight from the workshop, without opportunity for the preliminary trial requisite for all machines, and especially for one of novel construction. The result was what might have been expected. Minor defects of workmanship, such as might have been corrected, and which were corrected when too late, revealed themselves on the trial, and Ericsson was declared a loser under the rules of the competition.

The conditions were a run of seventy miles, back and forth, over a level stretch of track about two miles in length, at Rainhill, this being the only portion of the railroad completed. The contest was almost equal to a Derby day, in the interest and excitement it created, and the track on both sides, for its entire length, was lined with spectators on foot, on horseback, and in carriages. Five engines entered; but it was soon seen that the question of victory lay between two of them—Stephenson's "Rocket" and Braithwaite & Ericsson's "Novelty."

The "Novelty" was the favorite from the start. In beauty of design, in compactness of construction, in the combination of lightness with strength, it compared in appearance with the "Rocket" much as the Kentucky racer with the Normandy percheron. A glance at the cut on the next page will show its graceful outlines. By the use of blowers, to increase the draught as the speed increased, Ericsson was able to dispense with Stephenson's clumsy smoke-stack. To avoid thrust and heating, he applied the power to his driving-wheels horizontally, while Stephenson's connecting-rods were put at an angle of forty-seven degrees, counteracting the action of his springs. So while the "Novelty" moved along the track with perfect smoothness, the "Rocket" was as unsteady as a "jolly-boat in a gale of wind."

On the day of the competition—October 6, 1829—the "Rocket" was the only locomotive ready, and the trial of the "Novelty" was postponed until the 11th, when the pipe from the forcing-pump burst and brought it to a speedy termination. This was repaired



THE NOVELTY LOCOMOTIVE, BUILT BY ERICSSON TO COMPETE WITH STEPHENSON'S ROCKET, 1829.

in the course of the day, and the engine made several trips in the absence of the judges. On its trial before the judges, on the next day, a "green joint" yielded, and the choleric Ericsson somewhat too hastily, smarting under what he considered some unfairness, withdrew his engine, and the award was given to Stephenson, who had alone "fulfilled every stipulated condition."

Still, the judges in their report said "the appearance of the 'Novelty' is very much in its favor; the machinery is ingeniously contrived to work out of sight, and the whole form is as compact a machine as can be imagined." The London Times was enthusiastic in its praise. Describing an unofficial contest between the rival locomotives, during which Ericsson's was in working order, it said: "They ran up and down during the afternoon more for amusement than experiment, surprising and even startling the unscientific beholders by the amazing velocity with which they moved along the rails. But the speed of all the locomotive steam-carriages was far exceeded by that of Messrs. Braithwaite & Ericsson's beautiful engine from London. It was the lightest and most elegant carriage on the road yesterday, and the velocity with which it moved surprised and amazed every beholder. It shot along the line at the amazing rate of thirty miles an hour!

"It seemed, indeed, to fly, presenting one of the most sublime spectacles of human ingenuity and human daring the world ever beheld. It actually made one giddy to look at it, and filled thousands with lively fears for the safety of the individuals who were in it."

The prize went to Stephenson; the *succès d'estime* was with Ericsson. The eminent English engineer, John Scott Russell, who was present at Rainhill on this famous day, describing his experience, in the "Encyclopædia Britannica," edition of 1840, said: "The 'Novelty' had to be withdrawn, through a series of unfortunate accidents which had no reference to the character or capabilities of the engine, and we well recollect that it made a powerful impression on the public mind at the time. On the first day of the trial it went twenty-eight miles an hour (without any attached load) and did one mile in seven seconds under two minutes. This performance will now appear trifling, but at the time the sensation that it produced was immense."

There is no higher authority than Scott Russell, who here credits the "Novelty" with a speed of nearly thirty-two miles an hour. C. B. Vignoles, F.R.S., another British engineer, of equal authority, who rode with Ericsson that day, declared that he should never forget the look upon Stephenson's face when it shot by the "Rocket" on the occasion described by Mr. Russell. In his address, upon his taking the chair of the English Institution of Civil Engineers, January 11, 1870, Mr. Vignoles said: "The 'Novelty' was long remembered as the beau ideal of a locomotive, which, if it did not command success, deserved it." Still another British authority, John Bourne, says: "To most men the production of such an engine would have constituted an adequate claim to celebrity. In the case of Ericsson it is only a single star in the brilliant galaxy with which his shield is spangled." In considering these opinions, it should be remembered that our ideas of the Rainhill contest are derived from prejudiced accounts. Chief of these is that contained in Smiles' "Life of Stephenson," described by Knight's "American Mechanical Dictionary" as "ignoring facts and pettifogging the whole case; about as one-sided an affair as 'Abbott's Life of Saint Napoleon.'"

We may imagine the excitement following the announcement in The Times of the performance of the "Novelty" to which its chief attention was directed. Railroad shares leaped at once to a premium, and excited groups gathered on 'Change to discuss the wonderful event. The pessimists were silenced; the era of modern railway travel was inaugurated, and the world was called upon to adjust itself to wholly new conditions. To the young engineer of twenty-six years, who played his part so well on that day, was accorded the rare privilege of living long enough to witness the development of the new age he had helped to usher in. In the closing years of his life he could look back upon a "change in the physical relations of man to the planet on which he dwells, greater than any which can be distinctly measured in any known period of historic time," and this he had no small part in creating.

There was a notable gathering of scientific and professional men at the Rainhill trial. It was followed by a dinner, and the praises of the speakers made Ericsson known to all England as one of the rising men of his profession. Following his experience with the "Novelty," Ericsson built, in 1830, in conjunction with Braithwaite, two locomotives of elegant design and costly workmanship, called the "King William" and "Queen Adelaide." With these he expected to astonish the engineering world, but the restrictions put upon him by his associates prevented his fully carrying out his ideas, and the new engines did not meet expectation. The direct steam-blast, accidentally discovered by Timothy Hackworth during the Rainhill trial, and used by Stephenson, was superior to Ericsson's plan of producing draught by the suction of a fan-wheel, to which he appears to have adhered with a pertinacity that was characteristic; so he abandoned the field of locomotive construction and turned to other pursuits.

Ericsson was now a partner in a well-known London house, but in the routine of his profession he still found time for perfecting numerous devices and inventions, in many of which the methods of later years were anticipated or suggested. In 1830 he applied to the engines of a Liverpool steamer, the Corsair, the centrifugal fan-blower, afterward universally adopted upon American river steamers. He anticipated Sir William Thomson with a deep-sea lead, recording depths, without reference to the length of the line, upon a principle similar to his. This lead was patented in 1834, and came into extensive use, receiving the approval of navy officers and sea captains, and brought some thousands into the inventor's exchequer. For a hydrostatic weighing machine, patented in the same year, the London Society of Arts presented a prize, and a medal was also bestowed upon Ericsson by the first International Exhibition at London, 1852, for an instrument to measure distances at sea, an alarm ba-

rometer, which warned the mariner of an approaching storm by sounding a gong, and a pyrometer for measuring temperature up to the boiling-point of iron. By this last instrument, the error of Wedgewood in giving such high temperatures to fused iron, glass, etc., was demonstrated. An instrument for measuring the compressibility of water was also invented, and various devices for propelling boats upon the canals patented; in one of these was applied the mode of ascending heavy grades, now in use on the Swiss mountain railroads. A water-meter invented at this time was afterward used for a time by the Croton Aqueduct Department, New York; but the mistaken ideas prevailing at that time as to the degree of accuracy required in measurement of water interfered with its use.

Ericsson's study of the steam engine was constant, and he experimented with numerous ingenious devices for its improvement. From first to last he designed over five hundred steam engines. Into these he introduced many novelties, of which some have come into general use. Even from those he abandoned, because they produced no economical results, he derived valuable hints and experience. He tested superheated steam in an engine erected on the banks of the Regent's Canal Basin, London, in 1834. He built at Liverpool a centrifugal pump, worked by an engine formed of a hollow drum, turned on its axis at the rate of 900 feet a second, or 700 miles an hour, by the impact of steam against inclined planes projecting from the interior. Several rotary engines of novel design, a file-cutting machine, and an apparatus for making salt from brine were among the inventions which, from this time on, averaged three a year for thirty years.

In the midst of his labors upon the steam engine Ericsson persisted in his search for a substitute. In 1827 he built three engines, actuated by the expansion of air, and continued his experiments with hot air as a motor until 1833, when his first "caloric" engine appeared. Numerous modifications of this followed, as his investigations continued, and his researches into the nature of heat were finally recognized by the award of the Rumford Medal in 1856. His studies began in Sweden with his invention of a "flame engine," and in 1826 he contributed to the archives of the English Institution of Civil Engineers a paper describing his experience with this, and presenting his theories upon the subject of air engines. During the succeeding thirty years he expended over a quarter of a million dollars in building twenty-seven experimental machines for testing his theories, including the engines of his caloric ship, which cost one-half this total ($260,400). Nearly $100,000 more was devoted to his later researches into the nature of solar heat.

The "caloric" engine of 1833 was a sore puzzle to the scientific men of that day. They were unwilling to accept Ericsson's theories concerning it; but their own opinions as to the nature of heat were not sufficiently settled to enable them to explain clearly their own skepticism. Aristotle had told them that the first principle in Nature, through all its manifestations, was unity, and that these manifestations were always reducible to motion as their foundation, and Bacon had declared that "the very essence of heat, or the substantial self of heat, is motion;" but the science of thermo-dynamics was not yet established on the present basis of theory and experiment. It was not until 1849 that Joule, in his paper before the Royal Society, presented his final conclusion as to the mechanical equivalent of heat, and established the existence of an exact relation between heat and force, as the result of investigation begun by him in 1843, and by Mayer in Germany a year earlier.

Ericsson was guided by the accepted theories of his time, and his experiments had led him to the conclusion that heat is an agent that excites mechanical force without undergoing change. To his engine he gave the name of this supposed agent—"Caloric."

His first five-horse-power caloric engine was the sensation of London in scientific and mechanical circles. It was

visited by a large number of men of distinction, as well as by curious crowds of sightseers, and many years after its appearance it was still being learnedly discussed in engineering circles. Sir Richard Phillips, in his "Dictionary of the Arts of Life and of Civilization," records the "inexpressible delight" with which he witnessed the workings of this machine, and declared its action "capable of extension to as great forces as ever can be used by man." Dr. Andrew Ure believed that the invention would throw the name of James Watt in the shade; and Robert Hunt, F. R. S., the editor of the supplement to Ure's Dictionary, after the failure of the attempt to apply it to the purposes of navigation, declared that, in spite of this, "the expansion of air by heat will eventually in some condition take the place of steam as a motive power." Professor Michael Faraday, characterized by John Tyndall as "the greatest experimental philosopher that the world has ever seen," was first convinced and then bewildered. In 1834 he lectured on the new motor at the Royal Institution, but was compelled to inform his audience, which included many gentlemen of scientific reputation, that he did not altogether understand it. This was a sore disappointment to Ericsson, who had counted much upon Faraday's advocacy of his invention. At the end of his notes upon this lecture Faraday has written: "Must always work practically; never give a final opinion except on that."

Braithwaite does not appear to have joined Ericsson in his caloric venture. Their partnership was not a commercial success, brilliant as it was with engineering achievement. Frugal in personal expenditure, Ericsson was a spendthrift in gratifying his love for invention. To bring forth some new thing, or to transform the old in the alembic of his creative imagination, was his one consuming desire. Though he was far too thorough a master of his craft to occupy himself with conceptions not practicable in an engineering sense, his own means and the means of his friends were sometimes absorbed in ventures not profitable commercially. But were not the elder Brunel's Thames tunnel, his designs for the Capitol at Washington, his son's Great Eastern steamship, and innumerable other ventures of the most successful of men equally impracticable in the same sense? Even the greatest of generals sometimes loses a battle.

"Will it pay?" is the supreme test of contemporary appreciation, and Ericsson's inventions did not always pay; sometimes because the result he sought could be more economically accomplished in other ways, if less efficiently, and as often because a long educational process was required to convince those he would benefit of their need of what his genius had provided for them. The reception, no less than the conception, of ideas necessitates evolution. This is a weary world for those who see much beyond their fellows.

The steam fire engine was, as I have shown, a full generation in advance of the demand for it, and the field of locomotive construction was occupied by Stephenson, whose labors, concentrated upon the work of improving and adapting, were not disturbed by the buzzing of inventive conceits. Ericsson's investments in "futures," as they would be called on the Exchanges, were too heavy, and the financial difficulties resulting from this imprudence were increased by the enforcement of an obligation assumed on behalf of a friend. The firm of which he was a member had failed; the bailiffs were on his track, and for a time he enjoyed the hospitalities of "The Fleet" as a foreign debtor. In the year 1837, so disastrous to many others, he took the benefit of the "Act for the Relief of Insolvent Debtors," and secured his discharge in bankruptcy.

We had in our navy at this time a sailor, Robert F. Stockton, who united qualities rarely found in combination. An accomplished and experienced officer, showing an intelligent interest in all that concerned his profession, he was at the same time a man of fortune and family influence, and also an important

factor in the politics of his native State, New Jersey, which he afterward represented in the Senate of the United States. Captain Stockton was building the Delaware and Raritan Canal, and had invested his fortune, and that of his family, in it. The financial difficulties of 1837 compelled him to visit England to procure the means for completing the canal. Ericsson found in navigation on the Mississippi giving him an intelligent appreciation of his associate's efforts to improve the marine engine.

First, a model of Ericsson's propeller was built, and thoroughly tested in a public bath at Liverpool. Next, a boat, forty feet long, was launched upon the Thames. This, propelled by a double screw, attained a speed of ten miles an

MRS. JOHN ERICSSON, NÉE AMELIA BYAM. (FROM AN EARLY DAGUERREOTYPE.)

him for a time a congenial spirit, quick to recognize the value of his novel ideas on marine propulsion. The year before, Ericsson had made his first experiment with his screw propeller, associating with him in this enterprise a friend of Stockton's and a fellow-Jerseyman, Francis B. Ogden, then United States Consul at Liverpool. Ogden and Ericsson had been friends for years, and were connected in other undertakings, Ogden's previous experience in hour and demonstrated most conclusively its capacity by its feats in towing heavy vessels. As the propeller was especially adapted to naval needs, the potent Lords of the Admiralty must be convinced. They permitted themselves to be towed in their barge up and down the Thames at the rate of ten miles an hour, but gave the anxious inventor no hint as to their conclusions from the experiment. Quite by accident he learned that their sage determi-

THE VANDALIA—PIONEER PROPELLER ON THE LAKES.

nation was that no vessel could be steered if the power was applied at the stern. The author of this *à priori* conclusion, which experience could not disturb, appears to have been the then Surveyor of the British Navy, Sir William Symonds. It was a most illogical deduction from previous experience with paddles too near the stern.

This unwillingness to be convinced by facts is characteristic of the British Admiralty, and explains why they have so often been found in the rear of the procession in adopting the changes required by mechanical invention. They must needs wait until France approved the Ericsson propeller before accepting it. The civil engineers of England were equally blind to the merits of an invention which was destined to make a mock of their theories.

Stockton declared his contempt for the opinions of these pundits. Seeing with him was believing. He at once ordered a little propeller vessel, named after him, and sent it across the Atlantic under sail, and in command of a venturesome Yankee skipper, to whom the freedom of New York was granted by resolution of the Common Council upon his arrival.

Years after, from the British Patent Office came a request that the engine of this vessel should be purchased for its museum, to complete a series of models illustrating the progress of steam navigation. The Stockton was then (1866) in the possession of the Messrs. Stevens, of Hoboken, doing duty as a tug, under the name of the New Jersey. Ericsson tried in vain to get possession of the engine of this vessel, offering to replace it with a new one at his own expense. He was finally compelled to

announce the failure of this attempt. "Nothing," he wrote, "could induce the Messrs. Stevens, who claim to be the originators of screw propulsion, to permit the machinery of the real pioneer screw vessel to be placed in your museum. Accordingly, some time ago, the Robert F. Stockton was hauled out of the water and cut up, each plate being separated from the other, while the machinery was broken up and put into the melting-pot."

At the time of his association with Stockton, Ericsson was superintending engineer of the Eastern Counties Railway, one of the leading lines out of London, and had invented a machine to be employed in the construction of its railway embankments. Encouraged by Captain Stockton he resigned this position, and transferred himself to the United States, arriving here in the British Queen, November 2, 1839, being then in his thirty-seventh year. A gentleman who was in his employ at this time says of him: "His manner with strangers was courteous and extremely taking. He invariably made friends of high and low alike. With those in immediate contact with him in carrying out his work, he was very popular. He had few intimates of his own social level. With these his manner was very hearty, open and frank, and he was an excellent talker. To me, from my first intercourse with him to the last, he was always gentle, kind and considerate. In his habits of life he was frugal, but he never considered money or counted the cost of carrying out his mechanical conceptions.

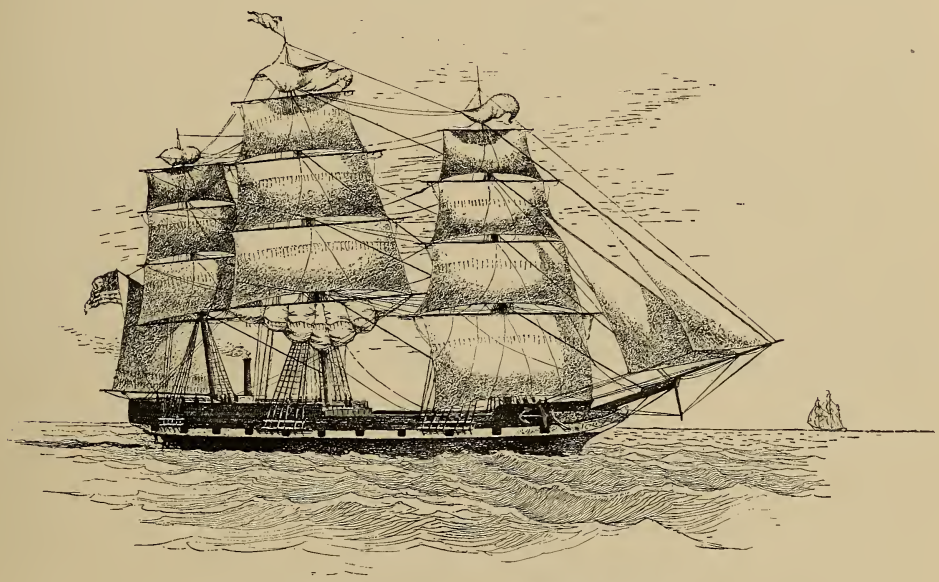
Three years before, on the 15th of October, 1836, Captain Ericsson had been married, at St. John's Church, Paddington, London, to Amelia Byam, daughter of Edward Byam, second son of Sir John Byam, formerly British Commissioner for Antigua. The bridegroom was then thirty-three years of age and the bride but nineteen. Mrs. Ericsson was a very handsome woman, intelligent, and of a generous disposition. She joined her husband after his removal to America, and they resided for some time at the Astor House, and afterward at the house he occupied in Franklin street, New York. Subsequently she returned to England, where she insisted upon residing, an amicable separation putting an end to Ericsson's brief dream of domestic happiness. He continued to contribute liberally to her support, and they corresponded until her death, in 1868. Her letters to him display respect and affection. None of his replies are preserved, but the invariable indorsement of the pet name of "Duck" upon her letters, which, according to his methodical habit, were all filed, indicates the feeling toward the one he was accustomed to describe as the most fascinating woman he had ever met.

Ericsson's acquaintance with Captain Stockton came just at the time when the inventor of the propeller was most in need of influential assistance to enable him to develop, in some more congenial clime, schemes in danger of perishing under the chilling influence of prejudice and indifference. Stockton was at this time in close association with the Messrs. Stevens, of Hoboken, who constructed locomotives and steamboats for the public highways in which he was interested. Considering the fact of the elder Stevens' claim to the screw, and considering, further, Captain Stockton's intimate relations with the Stevens family at this time, his active interest in securing the introduction of Ericsson's propeller into this country is significant.

There were then no steam vessels in our navy. The Demologos, built by Robert Fulton, in 1813, was never entirely completed, owing to the termination of the war in which she was to take part. In 1829, while stationed at the Brooklyn Navy Yard as a receiving ship, she was blown up, whether by accident or design was never determined, a large loss of life resulting. A second vessel, called the Fulton, had been built in 1837–38; but this was a failure, and lay a useless hulk at the Brooklyn Navy Yard until rebuilt in 1851. Thus the field of steam engineering, as applied to vessels of the United States Navy, was an open one. Many naval officers opposed altogether the introduction of steam into naval vessels, and

Ericsson's ideas as to its application were so bold and original as to still further alarm their conservatism ; but he had entirely convinced Stockton of their practicability, and Stockton was all-powerful at Washington. Captain William Hunter, of the Navy, had submitted a plan for a vessel with submerged wheels, and Stockton urged the building of a steam frigate on the plans of Ericsson, prepared in England to the sailing packet Massachusetts, afterward sold to the Government and used as General Scott's flag-ship in his landing at Vera Cruz during the war with Mexico.

The Princeton was built at the Philadelphia Navy Yard, under Ericsson's direction. As there was no specific authority for his employment, he was obliged to accept the assurances that he should be properly compensated for his



AUXILIARY STEAM PACKET SHIP MASSACHUSETTS, 1843.

previous to his arrival here. It was finally decided to build a vessel upon each plan. The usual delay attending government business occurred, and Ericsson had to wait three years before the vessel which he came over to build —the Princeton—was commenced. Before she was completed, in 1844, his screw had been applied to forty-one commercial vessels running upon the great lakes and along the coast. The first of these was the Vandalia, of one hundred and sixty tons burden. She was contracted for in December, 1840, and made her experimental trip in November, 1841, from Oswego to the head of Lake Ontario. The next was a coasting vessel, the Clarion, running to Cuba. In 1843 he applied an auxiliary screw time and for the use of his numerous inventions applied to the vessel. There was not, as he was accustomed to say, a portion of the Princeton as big as a pin's point which was not built from his designs. With the exception of $1000 advanced by Captain Stockton, nothing was paid him at this time, and it was not until the United States Court of Claims, in 1857, unanimously allowed him $13,930, that he established any legal claim against the government. This judgment represented, as Ericsson states in a petition to Congress, "not only the services and expenses of two entire years exclusively devoted to this work, but all the pecuniary compensation that your petitioner has received or can receive for the creation of the

first war steamer in any country of the class now universally adopted not only in the navy of the United States, but in all other navies of the world." A report presented by a committee of the Senate, in 1865, confirms this statement, declaring that the Princeton performed the service specified in the calculations, was entirely satisfactory to Captain Stockton, and highly advantageous to the United States. For this, it is added, "we are indebted to the fidelity, ingenuity and services of Captain John Ericsson, and for which he has never been paid."

Thus did the United States avail itself, without compensation, of the experience acquired at great cost by a private individual, and it has continued to make use, from that day to this, of ideas which he undoubtedly originated and first applied. If this does not violate the letter it certainly does offend the spirit of the constitutional requirement that private property shall not be taken for public use without just compensation, for property, as the United States Supreme Court has said, "is a word of large import." In 1866 a competent engineering authority declared that no screw propeller engine "has since been constructed to go below the water line which surpasses that of the Princeton in trustworthiness, durability, strength, lightness and mechanical excellence of performance. It was simpler and had fewer parts than any propeller engine ever put into a war steamer." Ericsson was the pioneer in applying power directly to the shaft turning the screw, so as to get rid of the complication of belts or gearing, and the engine of the Princeton was the first large example of this type. It marked a new departure and was at the time openly and unsparingly ridiculed by all the experts who examined it. In spite of them and their wisdom it did its work so perfectly and accurately that it wore out one hull, and another was built expressly for it.

(*To be Concluded.*)

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## E. WINDSOR RICHARDS.

IT has been well said that an historical sketch of the perfecting of modern processes of steel manufacture would afford probably the best glimpse that could be given of the career of Edward Windsor Richards. No steel works engineer on either side of the Atlantic is better known than he, and no one is there to whom practical steel metallurgy is more indebted for painstaking and successful effort in aiding its development.

Mr. Richards, who was born in 1831, at Dowlais, Glamorganshire, in Wales, comes of a famous engineering stock, the Richards family of Dowlais having been in the profession for three generations. Mr. Richards' father was engineer and general manager at the Rhymney Iron Works up to the time of his accidental death in 1839, and young Richards commenced his career in the engineers' shop at these works, afterward becoming a draughtsman in the engineer's office. In 1854 he was draughtsman and assistant engineer to his brother, Mr. Edwin Richards, at the Tredegar Iron Works, and from there he went to the Blaina Iron Works in 1857.

After occupying the position of assistant engineer at this establishment, he passed on to Ebbw Vale, where he put down the first steel works of that company in 1870, these being the second of the kind established in the Principality. In 1876 he left Ebbw Vale to undertake the management of the concern of Messrs. Bolckow, Vaughn & Co., at Middlesbrough, where he at once com-

menced designing the well-known steel works, which is considered to be one of the largest, if not absolutely the largest, in England. There he was the practical man to work out the then newly-discovered Thomas-Gilchrist process of basic steel making, and to him belongs the credit, by his practical knowledge, of pioneering this process to its present great commercial success.

Mr. Richards at once took an interest in the discovery and in the development of the process, giving many interesting details of it in his presidential address to the Cleveland Institute of Engineers, in 1880. "Messrs. Thomas and Gilchrist," he said, "prepared a paper giving very fully the results of their experiments with analysis. It was intended to be read at the autumn meeting of the Iron and Steel Institute in Paris, in 1878; but so little of importance was attached to it, and so little was it believed in, that the paper was scarcely noticed, and it was left unread till the spring meeting in London in 1879. Mr. Sidney Thomas first drew my particular attention to the subject at Creusot, and we had a meeting a few days later in Paris to discuss it, when I resolved to take the matter up, provided I received the consent of my directors. That consent was given, and on the 2d October, 1878, accompanied by Mr. Stead of Middlesbrough, I went with Mr. Thomas to Blaenavon. Arrived there, Mr. Gilchrist and Mr. Martin showed us three casts made in a miniature cupola, and I saw sufficient to convince me that iron could be de-phosphorised at high temperatures.

"I also visited the Dowlais Works, where Mr. Menelaus informed me that the experiments in the large converters had failed, owing to the lining being washed out. We very quickly erected a pair of 30-cwt. converters at Middlesbrough, but were unable for a long time to try the process, owing to the difficulties experienced in making basic bricks for lining the converters and making the basic bottom. The difficulties arose principally from the enormous shrinkage of the magnesia limestone when being burnt in a kiln with an upright draft, and from the failure of the ordinary bricks of the kiln to withstand the very high temperature necessary for efficient burning. The difficulties were, however, one by one surmounted, and at last we lined up the converter with basic bricks; then, after much labor, many failures, disappointments, and discouragements, we were able to show some of the leading gentlemen of Middlesbrough two successful operations on Friday, April 4th, 1879."

The news of this important success spread rapidly far and wide, and Middlesbrough was soon besieged by the combined forces of Belgium, France, Prussia, Austria and America. Mr. Thomas, in acknowledging the receipt of the Bessemer gold medal in 1883 for his invention, frankly admitted the assistance given by his colleague, Mr. Gilchrist, and added, "I am sure, too, that he and I are agreed in saying that the present position of de-phosphorization has been only rendered possible by the frank, generous and unreserved co-operation of Mr. Richards."

In recognition of the great services he had rendered in steel manufacture he was awarded the Bessemer Gold Medal by the Council of the Iron and Steel Institute in 1884. He was one of the original members of the Iron and Steel Institute in 1869, was elected a member of its executive council previous to 1881, became a vice-president shortly before 1884, and in 1893 was elected to fill the chair as its president.

For thirteen years Mr. Richards held the responsible position of right-hand man to Messrs. Bolckow, Vaughn & Co., when the anxieties inseparable from such a post began to tell upon him, and led to his acceptance, a few years ago, of an offer made by the Lowmoor Iron Company to take up the general management of their works. This position Mr. Richards now occupies, and under his direction the ancient prestige of these noted works has been well maintained, and Lowmoor iron is still holding its own in the markets of the world.

Troops of friends throughout both Europe and the United States afford the best evidence of Mr. Richards' popularity in scientific as well as social cir-

cles. His visit to the United States in 1881, and his graphic elucidation of the basic process at the Harrisburg meeting, in October of that year, of the American Institute of Mining Engineers are still fresh in the memory of many American metallurgical engineers.

Mr. Richards is now making a second visit to the United States, having arrived in New York early in October. This visit is one mainly taken for rest and recreation, and for the purpose of meeting his many friends among the engineers and iron and steel makers of that country. While, as it has well been said, Mr. Richards holds a high place among those who, by their skill and industry, have contributed greatly to the advancement of metallurgy as connected with the manufacture of iron and steel, he holds, as well, a warm place in the regards of all American engineers and iron and steel masters who, in their travels abroad, have at any time visited the famous steel works of Bolckow, Vaughn & Co. while Mr. Richards was manager, or the equally famous iron works of Lowmoor, where he now is.

Last month a banquet was tendered to Mr. Richards at New York in recognition not only of his eminent standing as an engineer and metallurgist, but of the personal qualities which he possesses, and which make him the genial, courteous gentleman that he is, and advantage was taken of the occasion by Mr. Richards to present to his warm personal friend, Mr. John Fritz of Bethleham, Pa., the Bessemer gold medal of 1893, awarded to him by the Iron and Steel Institute of Great Britain during Mr. Richards' presidency of that society.

## Current Topics.

The quantity of water precipitated in the shape of rain, and the amount of power represented by the fall of such water to the earth were made subjects of a few interesting figures at a recent meeting of the Engineers' Club of Philadelphia. It was calculated out, for example, that one inch of rain, falling upon an area of one square mile, is equivalent to 2,323,200 cubic feet, or nearly 17,500,000 gallons, weighing 145,200,000 pounds, or 72,600 tons. Assuming this water to have fallen from clouds about half a mile, or, say, 3000

feet, above the earth, we have, for the energy represented by it, 145,200,000 × 3000 = 435,600,000,000 foot-pounds, which, divided by 60 on the assumption that the inch of rain fell in one hour, gives 7,260,000,000 foot-pounds as the amount of work done per minute. This is equivalent to 220,000 horse-power. With pumping machinery working at the low rate of consumption of two pounds of coal per horse-power per hour, it would take 200 gross tons of coal to raise the water represented by the one inch of rain on a square mile to the assumed height of 3000 feet. As a matter of fact, rain often falls from clouds which are at much greater heights than 3000 feet above the ground, so that the figures just given are quite conservative ones.

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WITH all the talk that there has been about utilizing waste energies, it seems just a little peculiar that no promising scheme has yet been evolved to turn to good account the prodigious power waste which thus has been shown to go on with every rainfall of any account. And yet, while writing, a project comes to mind which was advanced about ten years ago, apparently in good faith, by some enterprising genius in the West Indies, to accomplish exactly this saving. What he proposed to do was to conduct the water from each roof, during heavy tropical rains, into a main pipe supplying a small turbine coupled to a dynamo. The electricity so developed by passing showers was to be stored in accumulators, and these, as they became charged in variable times, depending, of course, on the rainfall, were to be collected and stored at central depots, from which the power was afterward to be distributed. Unfortunately, however, this enticing scheme did not materialize, so that the field is still open for some one else.

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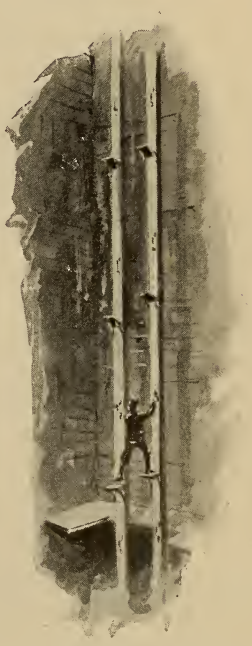
THE man engine, familiar enough to underground miners of a generation or two ago, is fast becoming a relic, and many engineers there are to-day who have never seen one, nor even an illustration of one. With but few exceptions in fact, at the famous Calumet and Hecla mine in the United States, for example, and in some of the old European mining districts, the man engine has long since been abandoned for the modern hoisting plant, and the experience of ascending or descending a mine shaft, platform by platform, on the steadily up and down-going rods of the old-fashioned apparatus is one for which all opportunity will soon have gone. To the many who do not know the man engine, even by name, it may be interesting to be told that it consists of little more than a rod, vertical generally, though sometimes inclined, depending upon the run of the shaft, extending from the surface to the bottom of the mine, and moved up and down, like a pump rod, by means of a steam engine or a water wheel. The length of travel of the rod commonly adopted is twelve feet, and at intervals, equal to the length of travel, small platforms are fastened to the rod, while corresponding platforms are fixed to the walls of the shaft on either side of the rod, and at points corresponding to the limits of the stroke, both up and down. A miner, in descending, say, steps on a platform on the rod just as the down stroke begins, and steps off on to the platform in the shaft which he reaches at the lower end of the stroke, repeating the operation until he reaches his destination. In ascending, similarly, a miner steps on to a platform on the rod as the upward stroke begins and leaves it at the end of the stroke. Ascent and descent, as will readily be understood, may proceed simultaneously without interruption, the



A DOUBLE-ROD MAN ENGINE.

fixed platforms on one side of the shaft being reserved for men ascending, and those on the other side for men descending, each man stepping on his proper platform on the reciprocating rod as it is vacated, at the moment of rest between the strokes, by the man going in the opposite direction. This form of single-rod man engine is even now in use in Cornwall, in England. In the Harz mines, in Germany—the birthplace of the man engine—the double-rod engine is in use, the two rods moving up and down alternately in opposite directions, and, accordingly, carrying the men at twice the speed that can be attained with the single-rod kind. The apparatus corresponds practically to a ladder with movable steps, the miner having nothing to do but to move slightly sidewise in order to place himself on the step about to go up or down, according as he wishes to ascend or descend.

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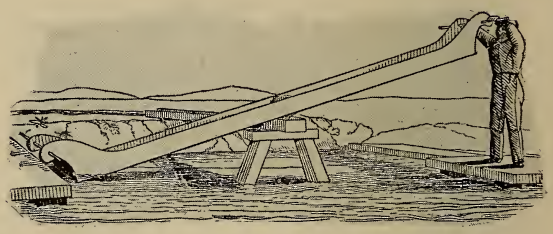
WATER-RAISING machines have probably been brought out in greater multiplicity of kind than most other apparatus now in current use, and an almost endless variety of pump modifications, from the simplest to the most intricate, can be unearthed by even slight research. What is known as the *jantu* of Hindostan and other parts of Asia, or a modification of it, is perhaps one of the earliest types of such machines, its extreme simplicity giving

A JANTU.

ample evidence that it dates from remote antiquity. The apparatus which has been, and is probably still, used extensively in India to raise water for land irrigation, consists simply of a hollow wooden trough, about fifteen feet long, six inches wide, and ten inches deep, placed on a horizontal beam, lying on supports fixed in the bank of the pond or river. One end of the trough rests upon the bank, where a gutter is prepared to carry off the water, and the other end is dipped into the water by a man standing on a stage, plunging it in with his foot. A



A DOUBLE-GUTTER JANTU.

long rod, with a weight at its farther end, is fastened to the river end of the jantu, and, passing over a gallows frame, raises the jantu full of water, and causes it to empty itself into the gutter. The machine can be made to raise water through any height, by placing a number of them one above another, the water from each being discharged into a reservoir sufficiently deep to admit the jantu above to be plunged low enough below the surface to become filled. Two forms of apparatus, only very slight modifications of the original Indian jantu, are shown on this page, and are given by Ewbank in his interesting book on "Hydraulics." One of them is a single-gutter, and the other a double-gutter machine, both of them, however, worked by man-power without the intervention of counter-weighted levers. The double-gutter machine is really nothing more than two single gutters united and placed across a trough or reservoir intended to receive the water. A partition is formed in the centre, and two openings are made through the bottom on each side of this partition, and through these the water that is raised escapes. The manner of operation is clearly explained by the sketches, a see-sawing motion being

given to the machine by one or more laborers. Sometimes openings are made in the bottoms of the troughs near the ends next to the operators. These openings are covered by flaps, acting as admission valves for the water, without making it necessary to wholly immerse the ends. The origin of these machines, so far as is known, has never been indicated, but, as remarked at the outset, they certainly date from very early times.

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In contrast to the very large generators of electricity—batteries and dynamo electric machinery—in such common use to-day, it may be interesting to note what is perhaps the smallest electric battery ever made and, no doubt, also the smallest generator of electrical or mechanical energy. This battery was constructed some years ago by one of the electricians of the Boston Telephone Company, and consisted of an ordinary glass bead, through which two wires, one of copper and the other of iron, were looped and twisted so as to prevent their coming in contact. The wires acted as the electrodes, and all that was necessary to produce a current was to place a drop of acidulated water in the bead. Certainly such a minute battery furnished but an infinitesimal current, but could be easily used in a delicate telephone ; in fact, it is said to have actually been used in signaling to a distance of nearly 200 miles.

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It has been pretty well demonstrated by experiment that shallowness of water exercises a retarding effect on the speed of ships; that, in other words, with the same amount of power, a vessel will go faster in deep water than in shallow water. What the difference has been found to amount to in a number of trials in the British Navy was told a short time ago by W. H. White, director of naval instruction and assistant controller of the Navy, before the Institution of Naval Architects. It appears that in one of the cases a vessel running in 12 fathoms of water required 13,260 horse-power to attain a speed of 20½ knots, while in water 30 fathoms deep she reached 21 knots with 12,550 horse-power, showing that there was a loss of about ¾-knot speed due to shallowness of water. In another case, that of H. M. S. Blenheim, in water 9 fathoms deep, the speed attained was about 20 knots with 15,750 horse-power. In deeper water, varying from 22 to 36 fathoms, however, the speed was 21⅓ knots. With no change, therefore, except depth of water, the speed rose 1⅓ knot, and the shallowness involved an expenditure of power at 20 knots which probably reached 3000 horse-power above what would have sufficed in deep water. Several other examples were given, but were scarcely necessary to enforce the inference that in trials of high-speed ships an appropriate depth of water is essential to a fair test of performance.

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Shooting old bolts out of locomotive frames instead of removing them by the time-honored method of drilling, or driving by heavy hammer blows, constitutes an interesting novelty in machine-shop practice which was recently carried into effect at the Hornellsville, N. Y., shops of the Erie railroad, in the United States. Removing old bolts from engine frames in the course of repairs, or rebuilding, has always been a slow and laborious operation, since the bolts, besides being tightly fitted from the start, are, in every case, badly rusted. One of the railroad employees, so the story goes, therefore conceived

A UNIQUE REPAIR SHOP TOOL.

the idea of driving them out by powder and shot, so to speak, and a steel, mortar-like piece of ordnance was accordingly improvised out of an old crank pin, measuring 10 inches in length and about 5 inches in diameter. A 2-inch hole was bored axially into this pin to a depth of 7 inches, constituting the bore of the gun, a small touch-hole was drilled through the side, with a vent hole further up to relieve surplus pressure of the powder gases, and a ram-like projectile was made to fit, measuring the same in length as the depth of bore. With about a half-ounce of powder as the driving charge, and the projectile placed directly beneath the bolt selected for experiment, the latter was completely driven out on the first discharge of the gun. Subsequently, a further number of bolts were driven out in the same way, successfully demonstrating the labor-saving qualities of this new tool. Not only at the Hornellsville shops, but at those at Jersey City and Susquehanna as well, it is now in use.

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ALTHOUGH the scare over the "deadly trolley" has somewhat abated, it is nevertheless true that many persons have been killed or injured by electrically-propelled cars, but in the way in which vehicles usually injure people—by running over them. Persons long accustomed to the slow-going horse-car do not allow enough time to get out of the way of the rapidly moving trolley-car, and accidents naturally result. The brake has been the weak point, as the ordinary mechanical braking apparatus can seldom be made to stop the car quickly enough in an emergency. The motorman has to operate both the current controller and the brake handle, and he is, therefore, very apt to become confused at the most critical moment. In a paper recently read before the American Institute of Electrical Engineers, Mr. Elmer A. Sperry has given an account of a very ingenious electrical brake, which seems to possess none of the faults of the ordinary apparatus. The brake proper consists of a crescent-shaped magnetic clutch, encircling the axle, but supported by the truck, and bearing, when in action, against a flat ring cast on the side of the wheel. The brake magnet has a coil, made up of a few turns of stout wire, entirely enclosed and sealed in metal, and the exciting current is generated by the car motor acting as a dynamo. Perhaps the most valuable feature of this apparatus is its simplicity of operation. It is worked by the same controller handle which starts the car and varies the speed. The motorman has only one thing to think of; when he wishes to stop the car, he turns off the current by simply swinging the lever over to the right. This operation automatically converts the motor into a dynamo for generating currents at very low speeds and, also, simultaneously cuts off all connection with the trolley current. The brakes are then applied by moving the handle back over the path which it has just traversed; the farther it is swung to the left, the more strongly the brakes are applied. The act of releasing the brakes again automatically re-establishes connection with the trolley, and reconverts the dynamo into a motor. While generating current, the converted motor naturally consumes mechanical energy, and as this energy comes only from the moving car, the magnetic brake is materially re-inforced by the motor. The car's entire store of energy is used to stop it, so that the faster it is going, the more powerful will be the braking action. When the wheels stop turning, the generating motor, connected with the axles, ceases to supply current, and none, therefore, exists to further apply the brake, so that a flat wheel from skidding is an impossibility.

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DURING some preliminary experiments with this brake, it was noticed that the retarding effect was much greater than would have been expected from the co-efficient of friction due to magnetic attraction or adhesion, and it was found that this extra effect was

caused by the currents set up in the masses of metal composing the brake magnet and the ring against which it bears. These currents always have such a direction that they tend to destroy the motion which induces them, and when the brake magnet was constructed so as to favor their production, they were found to have a much greater retarding effect than that due to direct magnetic adhesion. This is the principal reason for the peculiar shape of the magnetic clutch, which is in the form of a flat ring with a considerable gap in it. This construction also makes the removal of the magnet from the axle an easy matter. In some respects Mr. Sperry's brake would seem to be an ideal one, though it is not without drawbacks, one of which, worth bearing in mind, is that since the brake depends for its power on the current developed by the motor, it has practically no power when the car is standing still, and the motorman, hence, must use a hand brake to prevent his car from starting when standing on a steep grade.

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One of the good effects of Mr. Sperry's paper is the prominence which it has indirectly given to the subject of brakes for electric street cars. With the introduction of the trolley car the speeds at which it is run, and the question of their control have become matters of the gravest importance, and yet have been treated all too lightly. If there be city ordinances governing the permissible speeds of trolley cars within city limits, it is probably safe to say that they are violated in nearly nine cases out of ten during every hour of the day. From personal observation it would seem that often trolley cars are allowed to go, for certain distances, as fast as is deemed expedient by the motorman alone in his ignorance of possible results, untrammeled by any road regulations, and this means, in plain words, that they are run at speeds quite beyond reasonable limits. This seems to be particularly true on heavy down-grades, where really the greatest care should be exercised, but where the temptation to give a little exhibition of speed is often too great for the motorman to resist. He has done it many times before without harm to any one; why, therefore, should it not be repeated at his pleasure, especially if there be lost time to be made up, and a double purpose thus served? It is right here that attention should be again drawn to the well-known, but apparently much-ignored, fact that at high speeds the holding power of brakes is much smaller than at low speeds; that, in other words, the co-efficient of friction between a brake-shoe and a car wheel falls off considerably as the velocity of the wheel increases. It is on this account that on a down-grade a car speed may be reached at which the acceleration of the car, due to gravity, may much exceed the brake power, and the car will go faster and faster, despite all efforts of the brake. It is this phenomenon of which a motorman does not, as a rule, know and which, some day, may bring about an appalling accident, especially in view of the fact that heavy grades abound on electric roads almost everywhere. It is not likely that electric railroad companies are, at present, expending much effort in the mechanical science education of their employees, teaching them what dangers there are to be avoided in the running of their cars and how to avoid them; but a little instruction might stand them in good stead and yield profitable returns, perhaps, in the shape of immunity from serious mishaps and their various pecuniary after-effects.

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The other day someone asked, "Why would it not be a good thing for gas companies to supply consumers along their lines, who use moderate amounts of power, with gas engines if desired, not selling them, but charging fixed rentals, the engines always remaining the property of the companies, unless otherwise arranged for by mutual agreement, the whole arrangement being substantially like that followed by some of the electric light and

power companies who install fan motors for their customers and furnish the current to run them, at fixed sums for a certain time, the outfit being removed after that time unless the contract be renewed?" Continuing on this line, it was argued that since it is part of the business of gas companies to sell as much gas as possible, it is naturally to their interest to create and develop new outlets for their product, and that an increased use of gas engines would naturally be a most important factor in their sales operations. There can be no question that this would be the case, and it would seem equally certain that such an enterprise could be made profitable to a gas company notwithstanding the increased interest charges which would be entailed by the additional capital investment made necessary by the ownership of the greater or less number of gas engines requisite to conduct such a business. So far as is known, this idea has never been carried into practice. Gas engines are mainly used for domestic purposes, driving house-service tank pumps, small electric light plants in suburban residences, and the like, and for the operation of small manufacturing establishments in which the cost of the power installation is generally a very important item. Gas engines, at the same time, as everyone who has inquired into the matter knows, are rather expensive affairs, costing much more, power for power, than a steam engine and boiler combined, and this circumstance has always proved a serious drawback to those who would be most likely to use them, and with whom the necessity of practicing economy in the matter of original outlay for a power equipment is imperative. Could the engines be had in the same way as one can get a telephone, for example, at so much per month or per quarter of a year, it would be safe to predict a remarkable increase in the number in use.

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CABLEWAYS as means of transportation for both passengers and materials of all kinds have attracted attention for years past, and novelties of operation have been introduced from time to time which have helped to repeatedly bring them into prominence. Probably the latest development in this line is due to Mr. Richard Lamb, a New York engineer, one of whose projects contemplates the use of electricity as a cableway propelling agent, much after the manner set forth in the little illustration on this page. Two cables are to be used, one above the other, the lower one serving as an electric current supply main, while the upper one is a supporting cable for the vehicle, and, at the same time, serves as a return main. The current supply cable passes around a grooved wheel on the vehicle, which is revolved by the electric motor forming part of the outfit, and the power is thus transferred to points on the line where work is to be done, instead of being solely at one of the terminals, as in the case of a steam cableway employing a hauling cable. The operator, as shown, can ride with the trolley, and control all its movements by a resistance box and switches near at hand.

AN ELECTRIC CABLEWAY.

Yours faithfully

Ralph Hart Tweddell

# CASSIER'S MAGAZINE.

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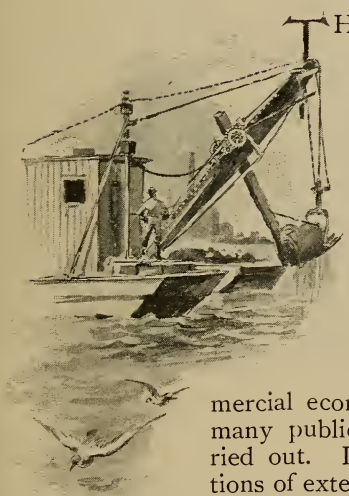
## THE STEAM SHOVEL.

*By A. W. Robinson, M. Am. Soc. C. E., M. Am. Soc. M. E.*



THE steam shovel is a distinctively American invention, and as such it furnishes a prominent example of how inventiveness and skill have produced a great labor-saving device, and one which closely affects the commercial economy with which many public works are carried out. Like most inventions of extended application, it has been a growth, or a development from an early form, and in its present stage it is not the work of any one man, but rather a varying form of the original idea as worked out by the different builders and designers who have taken it up.

These varying forms, however, follow the same general principles in the recognized type of machine known as the "steam shovel." They all employ a single dipper, mounted in a revolving crane, the dipper being pulled through its work by a triple-part hoisting chain attached to the drum of a winding engine. Besides this type, there are numerous other classes of excavating machines, adapted to special purposes and in successful use, such as the chain-bucket class, the clam-shell class and others, but with these the writer does not now propose to deal.

The primary object of the steam shovel is to supersede hand labor in shoveling; but with the advent of the steam shovel came increased and multiplied opportunities for its use, and it is now doing work which by hand labor would have been impossible. Inasmuch as in nearly all cases the material to be shoveled, or excavated, has to be hauled away, the chief function of the steam shovel is to dig the material and load it on cars. At first, wagons drawn by horses were used, and are still used in certain cases, but the wholesale manner in which the shovel digs, makes it necessary to take away its product by train loads in rapid succession, rather than by wagon loads. It is in this capacity and in its tirelessness in maintaining it that the economy of the machine over manual labor is manifest. The average laborer can shovel from a bank of fairly loose earth into a car or wagon, 5 feet high, not over 4 cubic yards, or 6 tons, per 10 hours, and where the material is at all hard or compact much less than this is accomplished. Assuming a laborer's wages to be $1.50 per day, the cost of loading the cars will be 37½ cents per cubic

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A STANDARD STEAM SHOVEL. WEIGHT, 40 TONS. BUILT BY THE BUCYRUS STEAM SHOVEL AND DREDGE COMPANY, SO. MILWAUKEE, WIS.

yard, or 25 cents per ton. If plowing, picking or blasting is necessary, the cost of placing the material on the cars may be $1.00 per cubic yard or over. The steam shovel, on the other hand, will dig and load as much as 1500 or 2000 cubic yards, equal to from 2250 to 3000 tons, in the same time, and this with the labor of 6 men, 3 on the machine and 3 to lay its track as it progresses. To do 2000 cubic yards in the same time, at 4 yards per day per man, would require 500 men, so that with a single powerful steam shovel 6 men can do the work of 500.

These figures are startling facts, and although they will necessarily vary greatly with different conditions, and in material of different degrees of hardness, they exhibit strikingly the marvelous superiority of this form of steam labor over hand labor. The economic value of the steam shovel, and of its allied types employed for dredging and submarine work, as applied to railroads, canals and national public works can hardly be overestimated. By the use of these machines it is possible to do a hundred-fold more work for the same cost, and much work, quite impossible by old methods, can now be done with ease.

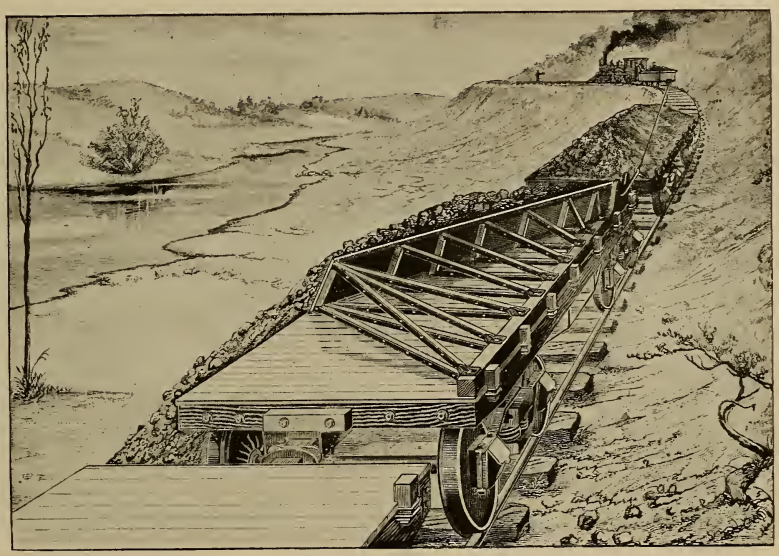
The principal field of work is naturally found in connection with railroad construction. Every railway, after the survey and location are defined, has a

certain amount of "cut and fill" in order to make its road-bed. Usually the level of the line is so determined that the volume of material taken from the cuttings just suffices to form the embankments. On new railroads the larger embankments are frequently left in order to save time and expense, and the depression is crossed by a trestle. After a few years, the decay of the trestle renders it necessary to fill in the depression, and this furnishes another class of work for the steam shovel. It is also employed in widening and straightening cuts, and in obtaining gravel for ballasting.

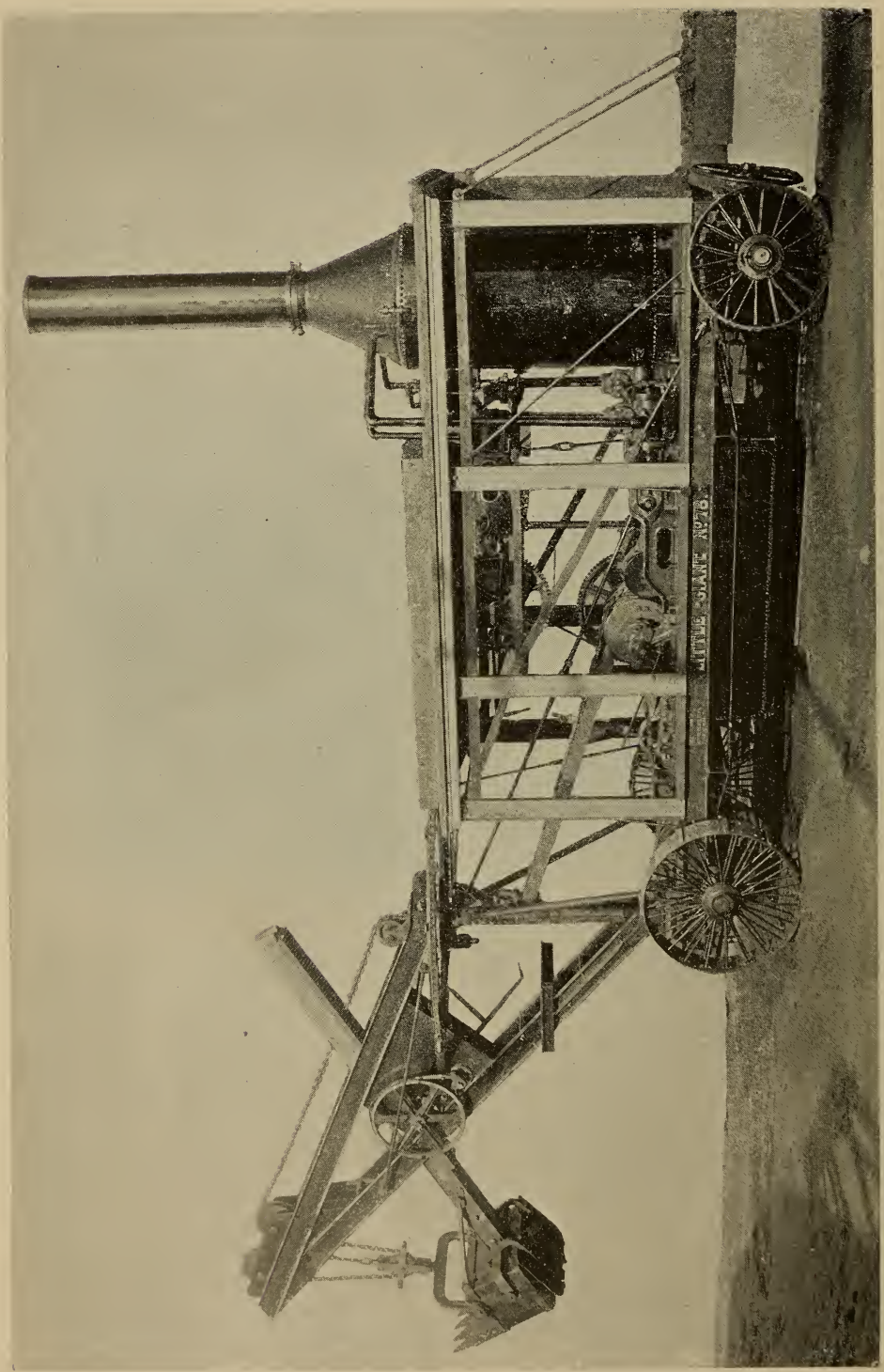
Wherever possible, the cars for carrying away the material are run in trains on a through track past the shovel, and the engine attached to them moves every few moments as the shovel loads the train. The rear car of the train is usually occupied by a double-faced plow called a "ballast unloader." Then a run to the "fill" is made, and the locomotive is detached from the train and connected by a long wire rope to the plow on the rear car. The brakes on the train are set, and the locomotive unloads all the cars in a few moments by drawing the plow the entire length of the train. In commencing a heavy cutting, it is not possible to run a train past the shovel for unloading, as it is then in a closed heading, or "through cut." This cut must, therefore, be made wide enough to allow cars to be run in on either side of the shovel, and switched out again as fast as they are loaded.

For railroad purposes the steam shovel must conform to certain requirements which are not necessary on other work. For instance, it must be restricted in size to the limits of tunnels and bridges, usually 10 feet wide by 14 feet 6 inches high, and it must also be mounted on standard gauge, centre-bearing trucks and provided with drawbars and brakes so that it can be coupled up in a train and be run at speed over the road. To construct a powerful machine within these narrow limits, capable of digging a cut, 50 feet wide and 20 feet deep, in any kind of material is a good deal of a problem, and it is interesting to study the manner in which it has been carried out.

In modern locomotive design the restrictions of these narrow limits are



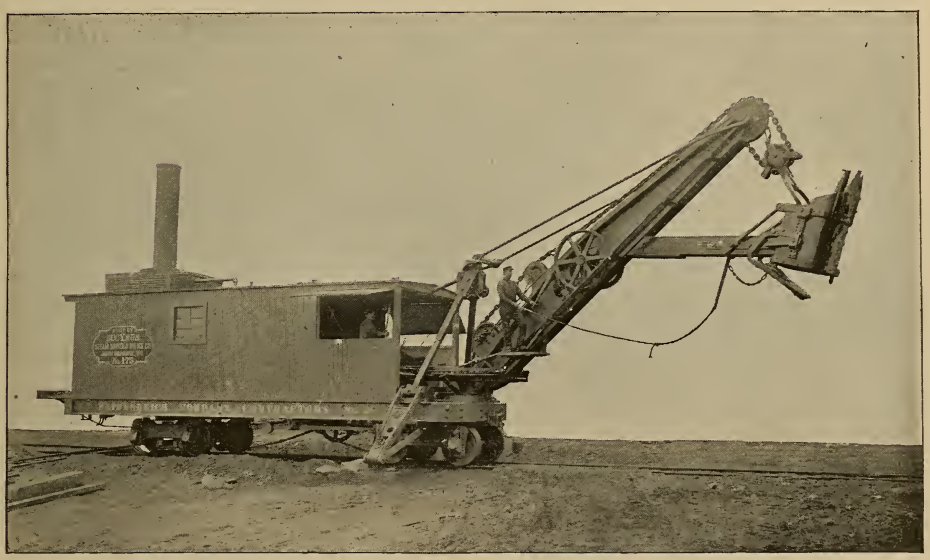
A BALLAST UNLOADER.




A TRACTION WHEEL STEAM SHOVEL, WEIGHT, 15 TONS. BUILT BY THE VULCAN IRON WORKS COMPANY, TOLEDO, O.

severely felt, and the resources and ingenuity of the mechanical engineer are taxed to fulfill all the requirements within such a narrow compass. When it is remembered that the present standard gauge of 4 feet 8½ inches was fixed upon when the average speed and load of locomotives was less than half what it is now, it will be realized that the task of doubling the power and doubling the speed, which is equal to increasing the steaming capacity four times, within the original narrow limits was no light one. From necessity, therefore, the locomotive has kept on growing and expanding, utilizing every available inch of space, strengthening its great lungs and steel muscles in order to give "staying power" to its running, so that now a modern engine with 19 x 26-inch cylinders, and a boiler with 1800 square feet of heating surface takes up no more outside width, and runs on the same gauge of track as its early predecessor of one-quarter the power. The problem of confining the steam shovel within these narrow limits, and, at the same time, maintain its stability and strength is correspondingly difficult, although the nature of the requirements is very different. Here it is necessary to reach far out beyond the narrow base on which it stands and encounter many tons of racking strains in all directions, due to the digging resistance of the great steel bucket with which the work is done.

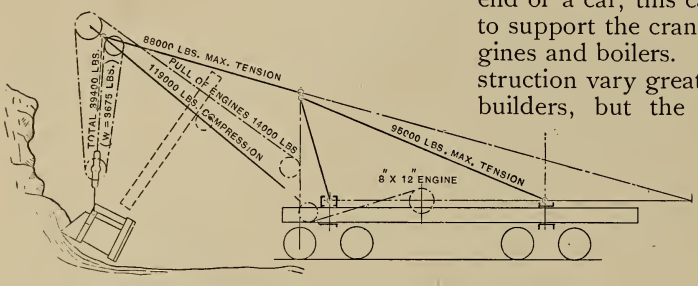
The strains upon a steam shovel, when working, are of two kinds, internal and external. Some of these strains are susceptible of calculation and others are not, and the proportion of parts can, therefore, be arrived at only by a process of testing in service. The internal strains are those that occur between all the structural parts by reason of the engine power applied, and can, therefore, be closely calculated. The external strain of the digging resistance at the teeth of the dipper, however, is a quantity that varies indefinitely, both in direction and amount. This external strain affects the stability of the machine, while the internal strain affects the strength of all its parts.



ANOTHER BUCYRUS SHOVEL. BOOM PATTERN. WEIGHT, 55 TONS.

No other class of machinery has to withstand such severe service and racking strains and concussions as dredging and excavating apparatus. Added to this, the steam shovel is compelled to

work in the midst of dirt and grit, gets but little care, and always has to work at its maximum pressure of steam and at its maximum speed. The pressure is never less than 100 pounds per square inch, and the speed is whatever the engines will do with the throttle wide open and the valves set to take steam

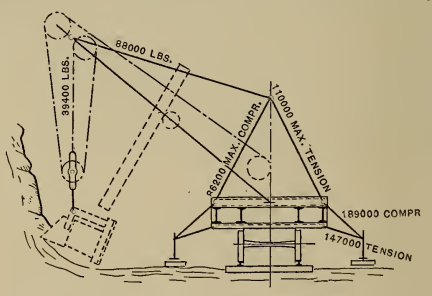



STRAINS IN A STEAM SHOVEL WITH BOOM IN FRONT POSITION.

full stroke. Three hundred revolutions per minute of the engines is a common thing.

Strain diagrams are given on this page of a standard railroad steam shovel as designed by the writer. In this machine the engines have double cylinders, 8 inches in diameter by 12 inches stroke. The strains throughout the machine are those generated by a mean effective pressure of 90 pounds per square inch on the pistons, and assuming a resistance to the dipper in the most unfavorable position. This mean pressure is nearly up to full boiler pressure, and would be attained only when the engines are running very slowly under maximum load and with the throttle wide open. The pull on the hoisting chain is proportional to the pressure on the pistons, and inversely as their speed. For example, the pressure on one 8-inch piston at 90 pounds per square inch is 4500 pounds. The diameter of the hoisting drum and ratio of the gearing are such that the total travel of one piston is 3.63 feet per foot travel of hoisting chain. The stress on the latter is, therefore, $4500 \times 3.63 = 16{,}335$ pounds. Deducting 15 per cent. for friction, the net pull is 13,885, or, say, 14,000 pounds. The hoisting chain is carried in three parts to the dipper; consequently the pull at that point is multiplied by three, less a further reduction of 15 per cent. for friction of the chain around the sheaves, or 35,300 pounds.

In its general arrangement, the modern steam shovel consists essentially of a steel dipper mounted on a revolving crane, or boom, upon the end of a car, this car being constructed to support the crane and carry the engines and boilers. The details of construction vary greatly with the different builders, but the mode of action is essentially the same in all of them. The dipper is provided with three motions—raising and lowering, swinging, and thrusting in or out. These three motions make the machine practically universal, and enable the operator to control it so as to dig effectively throughout a wide range, and dump in the right place. The dipper is of steel, and is carried on the end of a dipper-arm. The latter is




ANOTHER STRAIN DIAGRAM WITH BOOM IN SIDE POSITION.

double, so that the hoisting chain can pass through it. A rack on the upper side of the dipper-arms, and pinions on the suspension shaft furnish the means for controlling the "thrusting" movement.

The digging is done by hoisting the dipper by the chains attached to it and, at the same time, holding it into its work through the racks and pinions. A brake on the pinion shaft serves the latter purpose. When necessary, power is applied to these pinions to thrust out the dipper and make it dig

A BARNHART SHOVEL, SHOWING ALSO A METHOD OF DISPOSING OF THE EXCAVATED MATERIAL.

further into the bank as the work progresses. Ordinarily this is done by a friction-clutch and driving mechanism attached to a sheave over which the hoisting chain passes, and which is "pocketed" to fit the links of the chain and make the latter a driver.

On larger shovels and for digging in hard material a pair of independent reversing engines are employed and connected to the rack and pinions on the dipper handle. The hoisting chain passes over suitable sheaves to the drum of the engines on the car. This drum runs loose on its shaft and is connected with the driving gear of the engines by a powerful friction-clutch that can be thrown on or off by the operator. Similar gearing and clutches provide means for swinging or revolving the crane through a half circle or more.

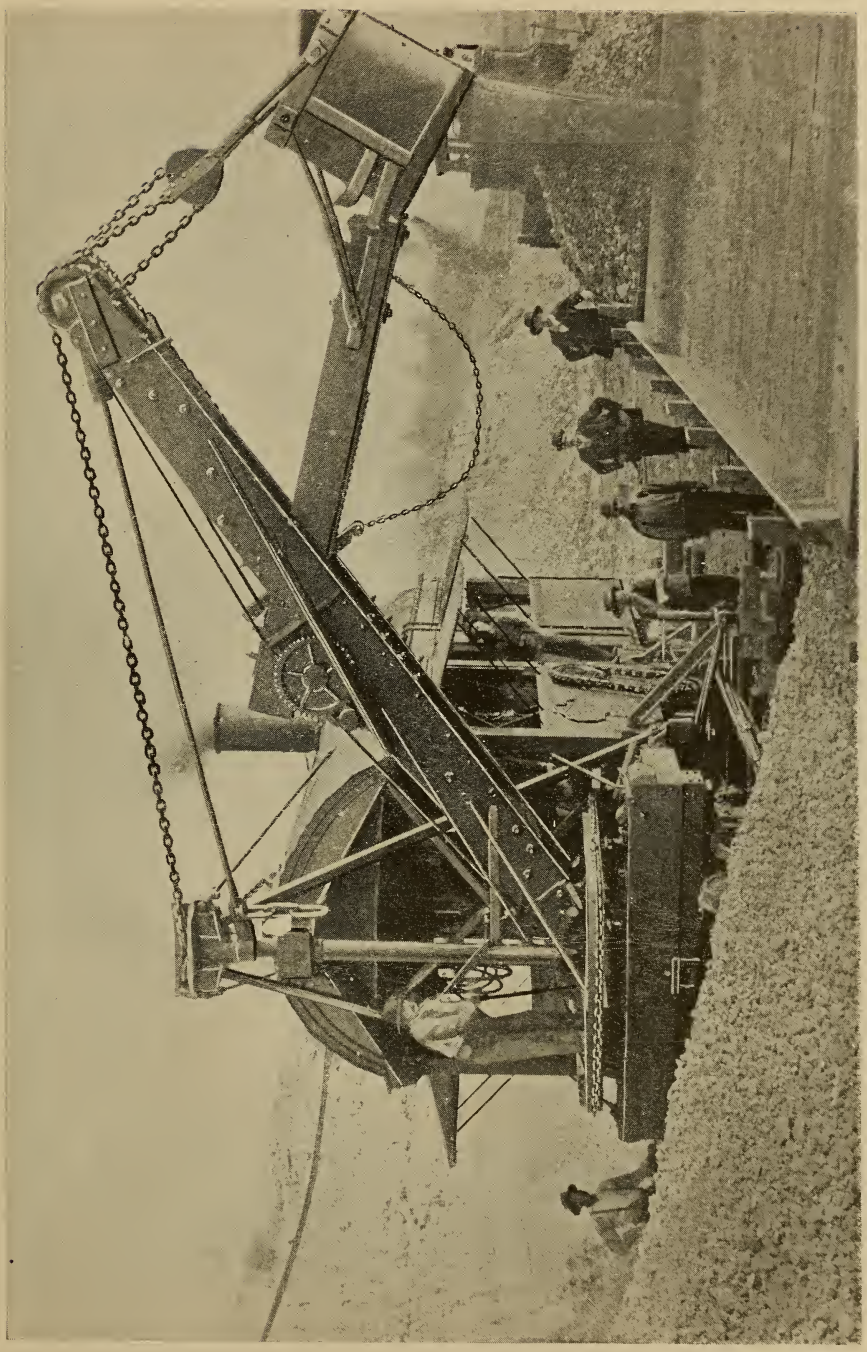
As soon as the dipper is dropped into position, the operator throws in the hoisting clutch, and the engines at once begin to haul in the chain and pull the dipper upward, describing an arc of a circle through the bank. The radius of this arc can be varied by the rack and pinion movement, so that a sufficient cut is taken to fill the dipper. As soon as the dipper is clear of the bank, the swinging clutch is thrown in to swing either to the right or left, as desired, and the dipper is brought around over the car alongside. The hoisting has, meanwhile, continued during the swinging, so that the dipper is at the proper height when over the car. The cranesman now pulls the dump-lever, and the bottom of the dipper swings open and allows the contents to fall out. The return swing and drop is quickly made, and the operation is repeated until all the material within reach of the dipper has been excavated. All these movements follow each other so rapidly that the great steel dipper seems to leap through the air direct from the shoveling place to the car and, emptying its load, to dive back again and attack the hardest

bank with a force that is irresistible. Four to five times a minute its load of a couple of tons is thrown out, and the cars are loaded so fast that the locomotive has to keep them constantly in motion in order to evenly distribute the material along the train.

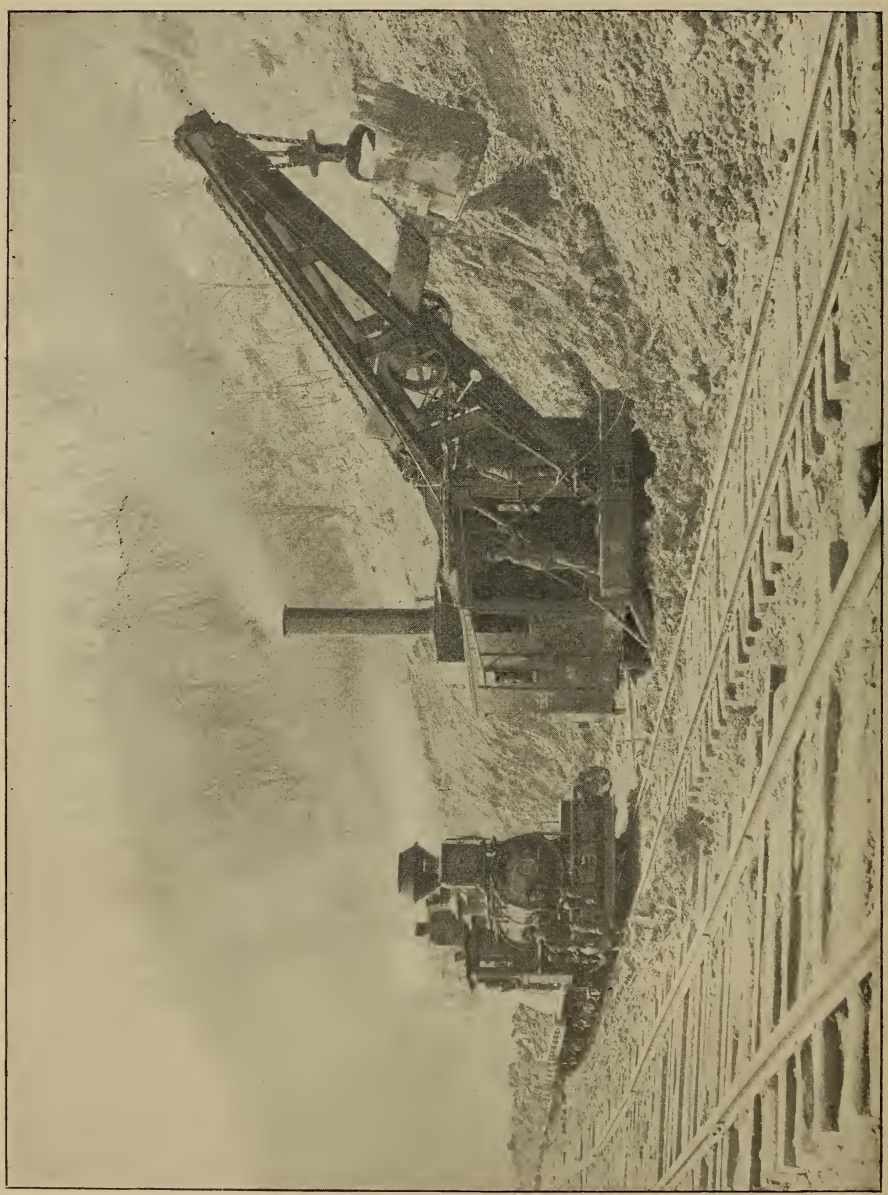
Considerable skill is needed to run a shovel, but by practice the men become so accustomed to the work that it becomes a second nature to them, and the great machine seems a thing imbued with life under their hands, and its movements instantly respond to their will. Three men constitute the crew—the engineer, the cranesman and the fireman. Besides these, several laborers are needed to lay track, etc.

In a recent example of a powerful machine designed by the writer, and built by the Bucyrus Steam Shovel and Dredge Company, So. Milwaukee, Wis., for work on the Chicago Drainage Canal, the car is framed of four 15-inch steel I-beams, 75 pounds per foot, very strongly braced and trussed to form a solid floor. The hoisting engines are proportioned to exert a pull of 76,000 pounds upon the dipper, and the entire machine is proportioned to withstand the stresses set up by this pull and the concussions of encountering immovable resistances in any direction. The car body, or house, is similar to freight car construction, and does not in any way contribute to the support of the boom or strengthen the construction. The strains from the boom are directly met by a pyramidal "A" frame consisting of two forward compression members and one back tension member. The "A" frame is of solid forged steel and is pin-connected to steel castings. One striking feature about the design of this machine is the low and insignificant-looking "A" frame from which the boom is suspended. The height of this is primarily fixed by the standard railroad limit of 14 feet 6 inches, in order that the frame will not have to be removed or taken down when traveling over the road. In its working position the boom stands far above this, the point being 22 feet above the rails. The boom can be lowered for transportation to a horizontal position, or let down upon a flat car—an operation which is arranged to be done by the power of the hoisting engines, and which occupies but a few minutes. The practical effect of the low "A" frame is to increase the tension on the boom guys and the compression on the boom itself, because the angle between these two members is more acute than it would be with a higher point of suspension. On the other hand, the strains upon the "A" frame legs are less for the low position than for the high one, because the boom suspension guys and the back tension guys are more nearly in line. The frame, therefore, is under very little strain when the boom is in front, but its members come into tension and compression when the boom is at the side. Stability is given to the machine by the two jack-arms which extend out on each side. These form, practically, a pin-connected extension of a truss across the point of the car, and upon this truss the "A" frame is erected, and upon its lower side is the truck centre-plate. On the ends of the jack-arms is a large steel screw which is screwed down to a bearing upon blocking when the machine is at work. In this way the lateral base of the machine is increased from 4 feet 8½ inches, or the gauge of the track, to 18 feet, the distance between the jack-screws.

The machine illustrated on page 191 may be taken as a representative railroad shovel, as it is built to conform to railroad requirements. For contractors' use, however, it is possible to pass beyond the restrictions imposed by a car on standard gauge track, 10 feet in width and 14 feet in height. In this way the dimensions can be increased to fulfill almost any desired conditions. The Bucyrus Steam Shovel and Dredge Company, of South Milwaukee, Wis., has recently completed a large shovel which runs on a track of 20 feet gauge, and which is capable of making a cutting 60 feet wide and depositing the material at a radius of 65 feet from centre of the track, and at 30 feet elevation. Such a machine is used for



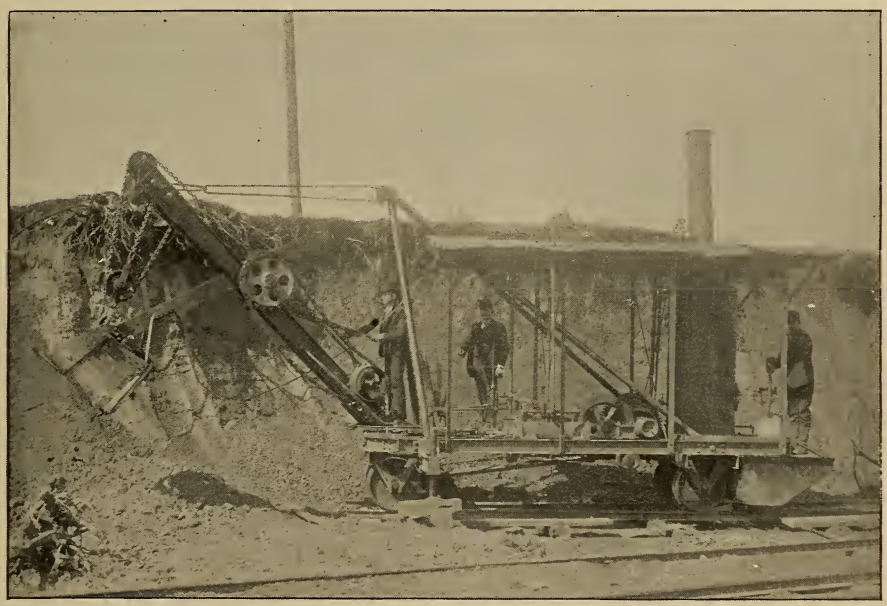
A BARNHART SHOVEL, BUILT BY THE MARION STEAM SHOVEL COMPANY, MARION, O., WORKING IN FURNACE SLAG.



A RAILROAD SHOVEL, CRANE PATTERN. WEIGHT, 50 TONS. BUILT BY THE BUCYRUS STEAM SHOVEL AND DREDGE CO.

building a canal for drainage purposes, and the great reach and elevation of the dumping point is necessary in order to deposit all of the material upon the banks without the use of cars to haul it away.

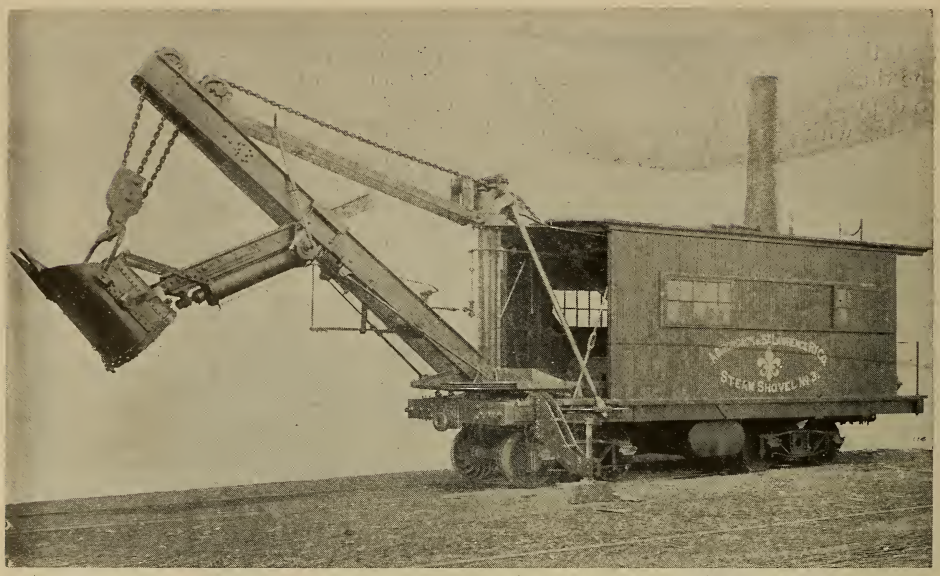
The other extreme in size is found in the small road shovel, built to supersede hand labor in loading wagons, etc. This shovel is illustrated on this page. There is, however, a limit in size beyond which a steam shovel cannot



A SMALL BUCYRUS ROAD SHOVEL.

economically be reduced, as then the cost of operating it becomes too great in proportion to the work done. This shovel has a capacity of 200 cubic yards per 10 hours, and weighs 10 tons.

Although the machines thus far described constitute, in their general character and work, the bulk of the steam shovels in use, there are yet many other fields of work to which special adaptation has been made, and in which the steam shovel has proved itself a most potent factor, both in the development of these new fields, and in their economical working. The author cannot do more in the present article than to briefly touch upon a few of these special applications. Sewer building, for example, has always been a difficult class of work to which mechanical excavation can be successfully applied. The conditions are so varied that it is only in cases where a large amount of approximately uniform work is to be done that special machinery is profitable. The steam shovel for this work takes the character of a car carried on a track of very wide gauge—wide enough to span the trench to be made. The dipper-arm and boom are then so proportioned that the machine can dig to the desired depth below the track. The material is either dumped on cars or on a conveyor which carries it back and fills up the trench behind, the sewer having been laid in the meantime. A recent machine of this kind has been built from the writer's designs for a main outfall sewer, 15 feet in diameter, in Chicago. The trench is 16 feet wide and 20 feet deep, with perpendicular sides, and the machine is carried on a track of 18-foot gauge, the rails resting partly on the piling with which the




A RAILROAD SHOVEL, BUILT BY THE INDUSTRIAL WORKS, BAY CITY, MICH.

trench is lined, and partly on the bank. This machine weighs 40 tons, and excavates 1000 cubic yards a day in moderately stiff blue clay. It will readily be seen that the field of work which this opens up is very large, and that smaller machines can be built to suit almost any range of work.

In placer mining there is a large and increasing use of steam shovels, and the conditions under which they have to work call for special treatment. Since the decadence of hydraulic mining, attention has been called to the large dry placer deposits which exist in all the Western and Pacific States and territories of America. The various methods of treating, washing and extracting the gold from the gravel in these deposits call for some ready, powerful and cheap method of excavating large volumes of the gold-bearing gravel. When it is borne in mind that the gold in most of these deposits does not average more than a few grains in weight to the ton, it will be seen that economy in handling large volumes of material is absolutely necessary to success. Placer deposits frequently consist of hard gravel in which there are many boulders of all sizes up to a ton or more in weight, and the shovel for this work must be capable of handling this kind of material. Other conditions, such as scarcity of water or fuel, difficulty of access by mountain roads, or by mule back, all enter into the case and confront the engineer as a problem with many sides and great difficulties. All these have been successfully surmounted in adapting the steam shovel and allied machines to placer mining.

In all brick yards, too, the digging of the clay from its natural bed is the initial operation, and its natural tenacity renders this a slow and costly process by hand labor. A moderate-sized steam shovel, properly built for the work, will readily take out material for half a million bricks per day, and no modern brick yard of large capacity is now complete without this labor-saving machine.

In phosphate mining—an industry known principally in South Carolina and Florida—steam shovels and other excavating machines are largely used for the land deposits, as well as dredges for the deposits under water. Generally the phosphate beds are covered with a layer of earth which must first be stripped off. Steam shovels serve equally well for the stripping as for the

mining. For small operators who cannot afford a double plant—one for stripping and one or more for mining—the writer has designed a special shovel with a traversing dipper handle and shaft. This is so arranged that the entire digging apparatus can be run up on the boom by hydraulic power, in position to dig off the top layer of earth and cast it over on the waste dump, and when this is done the dipper shaft is run down to the proper position to dig the substratum of phosphate and load it into cars.

In iron ore mining the steam shovel may be said to have worked almost a revolution. The old system can no longer compete with the enormous output at low cost which is attained by steam shovel mining. In northern Michigan and Minnesota, in the United States, steam shovels load the iron ore directly on cars from its natural bed after being stripped by other shovels, and this at a cost of only a few cents a ton. In this way the cost of the actual mining and placing the ore on board cars is one of the smallest factors in the cost of the finished product. The phenomenally low prices which have latterly ruled in the American iron market are, in large measure, directly traceable to the steam shovel method of mining the ore.

Strange as it may seem, even coal is mined by a similar process in several localities. As a rule, coal lies deeper and the veins are thinner than iron ore beds, but, nevertheless, there are beds of coal which, with 40 feet of earth over them, are stripped and laid bare by the steam shovel, so that the entire bed can be removed in the light of day.

This brief reference to some of the principal uses of the steam shovel, although not complete, will serve to illustrate the variety of purposes for which machinery of this kind may be employed. The great allied field of dredging by means of powerful floating machines, analogous in principle to the steam shovel, has not been touched upon, nor yet the great variety of excavating machines in use which are built upon other principles and cannot properly be called steam shovels. Nevertheless, enough has been said to make it clear that the steam shovel plays by no means an unimportant part, not only in those large works classed as public improvements or engineering works, but also in many of the vital industries which affect the commercial economy of a nation.

# ENGINEERING FALLACIES.

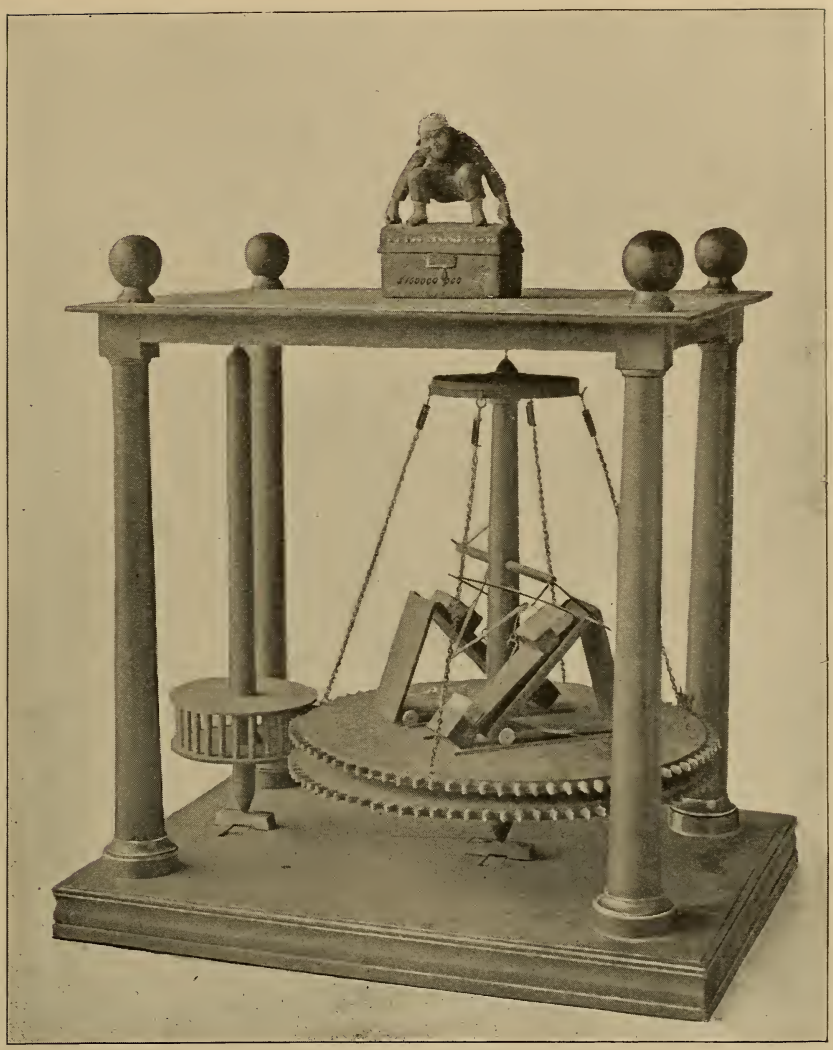
*By Henry Morton, Ph. D.*

THERE are a number of popular fallacies which the mechanical engineer in the course of his professional work is likely to encounter, and which, as experience has shown, may sometimes even lead him astray when met with in a new guise, and which are also occasionally not easy to expose or explain to the ordinary observer. As my own experience during the last thirty years has brought me in contact with quite a number of these, I believe that I may do a service to the younger members of the profession by putting on record some of my experiences and some general principles or rules for dealing with such subjects which I have found eminently useful.

In the first place, though it may seem almost superfluous to mention such a thing, every engineer or investigator who undertakes the examination of any new project involving an assumed discovery of new laws or modes of action among the forces of nature, must hold with absolute confidence the great doctrine of the conservation of energy, with its direct corollary relating to what is technically called perpetual motion. This doctrine may be briefly stated as follows :—No item of energy in the universe ever perishes, nor is any item of energy ever added to the existing supply ; the only changes possible are the transformations of energy from one orm into another. Thus heat energy may be developed from electric energy, or from chemical energy, or from mechanical energy, but for every unit of heat energy developed, an exact equivalent of the other form of energy must disappear. Proteus-like, energy can take all shapes, but must leave one to become another. It can only transform, but in no wise multiply itself.

It is just as impossible to create energy as to create matter, and if any process is presented which claims to get out of a pound of coal more energy than it is known to possess, or out of the work of a horse more than its known amount, it should be regarded as precisely equivalent to the claim that ten chairs could be made into eleven or twelve by some special grouping or arrangement of them. In other words, we should regard it as either a piece of legerdemain, or of oversight and error of observation. In one of its simplest forms of application this principle amounts to the familiar statement of the impossibility of "Perpetual Motion." It may be well to remark here that this term, as used in this connection, does not mean indefinitely continued motion, for this, where no resistance is encountered, might manifestly exist, and may be said to be illustrated by the heavenly bodies.

Perpetual motion means the doing of work without expenditure of energy, as would be illustrated by a machine which once started would continue to saw wood or even overcome the friction of its own journals without further supply of energy. Strange as it may seem, even in this crude form, this fallacy still crops out, and I have within a year encountered it among intelligent and, in a general sense, well educated people, and I will, therefore, venture on a word



MODEL OF THE READHEFER PERPETUAL MOTION MACHINE.

of suggestion as to the best means of treating such cases.

In the first place, as a rule, at the present time even, those who believe they have discovered a means of creating energy, by the use of mechanism, do not go so far as to suppose that a machine can move itself, but only believe that by certain combinations a given amount of energy or work may be developed or increased into a larger amount, and in such cases the best argument to open their eyes to the fallacy of their plan is the "*reductio ad absurdum*," which will be reached by suggesting the connection of the end of their mechanism where the increased "power" is supposed to be available with the starting point where the small driving force is to be applied. Thus, suppose an inventor of this sort comes to you with a train of wheel work, levers, etc., by which one man is to propel a train of cars or the like. It is generally useless to follow out the steps of the mechanism and to point out ex-

actly where a false assumption has been made. If he can appreciate the point at all he will consider it simply as a matter of detail which he will be able to improve on further study; but if you pick out the final wheel which is to give motion to the whole train of cars he will, of course, admit that it will turn around with many times more power than a man could exert. You will then propose that this should be connected directly with the crank or lever at which the man was to work when it would manifestly do the man's work and have a large amount of power left over to run the train, thus dispensing with the man's services as soon as he had started the apparatus, and making the machine self-driving.

In curable cases where no fraud is involved, this will be sufficient, but too often the inventor of a perpetual motion machine is beyond the reach of reason, as was the case with the one who came to Arago for an explanation of the fact that his perpetual motion machine would stop. Not infrequently such plans involve a mechanical fraud by which the driving force is conveyed to the visible mechanism from a concealed source of power. In such cases there is an opportunity of applying close and inclusive observation and some ingenuity in order to detect the fraud.

An admirable instance of this is furnished by the history of a small model in the collection of the Franklin Institute at Philadelphia, which was made about eighty years ago by Isaiah Lukens at the suggestion of Mr. Nathan Sellers for the purpose of exposing the fraud involved in the then famous Readhefer perpetual motion machine, in which large sums of money were sunk, as they have been in the "Keely motor" and like schemes, more recently. This model, represented on the page opposite, consists of a horizontal circular table, attached to and supported by a central vertical shaft, resting on a pivot below and steadied by a journal held in a frame work above. Two inclined planes, mounted on wheels, rest on this circular table and each inclined plane has on it a car containing two removable weights. The inclined planes, and also the cars, are attached to levers which are supposed to transmit to the central shaft the tendencies of the inclined planes to run from under the cars and of the cars to run down the inclined planes, and these tendencies are supposed to cause rotation of the central shaft, carrying with it the table and all the parts on it.

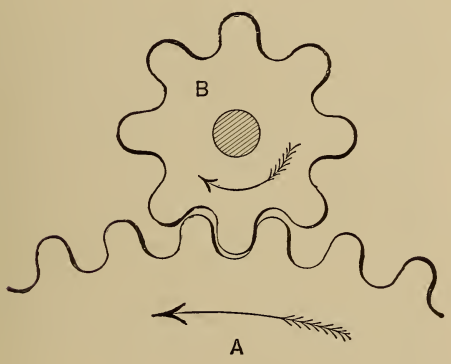
This arrangement is admirably simple in more senses than one, but, wonderful to relate, it seems to work. If the weights are taken out of the cars, the machine comes to rest, but it starts up again as soon as they are replaced, and, under favorable conditions, will continue to run indefinitely. Here is a phenomenon which might well startle a novice, but he would do well to hold fast to his faith in the conservation of energy and insist on a further investigation into the interior of the apparatus. Here is what such an investigation would reveal:—

A train of clock work driven by a spring is concealed in the base of the machine and can be wound up by a slight motion of one of the ornaments on the frame of a glass case, which covers and locks up the model beyond seeming possibility of tampering. This clock-work drives a small plate on which rests the pivot of the central vertical shaft, and the various frictions are so adjusted that when the cars are loaded, the weight so given will make the friction of the little plate sufficient to drive the shaft, but when the weights are removed this friction is too slight. An attendant, once a day, touching the outside case for a moment in pretense of dusting or the like, can keep it wound up perpetually. Such then is the structure and such the mode of operation of this very ingenious model whose history, which is also extremely interesting, I will now give.

In the year 1812, Mr. Readhefer applied to the Legislature of Pennsylvania for a grant of funds to carry out his great invention of perpetual motion, and a committee of experts, consisting of Messrs. Henry Voight, Robert Pat-

terson, Nathan Sellers, Oliver Evans, Archibald Binney, Lewis Wermerag, Josiah White, and Samuel D. Ingham, was appointed to examine the matter The machine to be examined was set up in a building near the banks of the Schuylkill river in Philadelphia and, on a day appointed, the above-named commissioners went out to inspect the apparatus, Mr. Nathan Sellers taking with him his son, then a lad, but afterward the father of Professor Coleman Sellers, E. D.

When the commissioners arrived at the location, they found that the door of the room containing the machine was locked and the key missing, so that their study was confined to an inspection of the apparatus through a barred window. Even this limited view, however, was enough for the sharp eyes of young Coleman Sellers. The machine had a set of teeth on the periphery of the rotating table which geared into another wheel whose axle was supposed to transmit the power to some other point where work was to be done. Young Sellers, looking through the window, noticed that the faces of the teeth in the two wheels were polished by wear on the wrong sides. This will be clear from a glance at the accompanying diagram. Let A be the rotating table driving the gear wheel B in the direction of the arrows; then, clearly, the front faces of the teeth of A will press against the rear faces of the teeth of B, and these faces will be polished by friction. If, however, it is the front faces of the teeth of A and the rear faces of those of B that are polished, then it is manifest that B must be driving A. This is what young Sellers noticed and pointed out to his father as proving that the perpetual motion machine in place of driving the gear wheel was being driven by it from a concealed source of power.




Satisfied as to the fraudulent character of the Readhefer machine by this observation, Mr. Nathan Sellers concluded that others might be best satisfied by a sort of homeopathic object lesson. He, therefore, went to Mr. Isaiah Lukens, a very skillful mechanician of that date, and had him construct the model above described. This he at first exhibited to a number of persons, including Mr. Readhefer himself, without explaining its true "inwardness." Mr. Readhefer was so impressed that he privately offered Mr. Sellers a large share of his inventions if he would tell him "how it was done." It is hardly necessary to say that this offer was declined and the true "*modus operandi*" in due time made public. This matter is so curious in many respects that I will here insert a copy of the resolution under which this commission acted:—

"WHEREAS, The interference of the Legislature of Pennsylvania in causing an inquiry to be made relative to the perfection or imperfection of newly invented machinery is not without precedent;

"AND WHEREAS, It has been represented that Charles Readhefer, of the County of Philadelphia, has invented a machine declared not only by the inventor, but by many intelligent persons, to possess the power of self-motion;

"AND WHEREAS, Should it be ascertained that these opinions are correctly founded, not only great honor would be conferred upon the Commonwealth, but incalculable advantages would be derived from the invention by the people of the United States especially, and by mankind in general;

"AND WHEREAS, On the other hand, should the machine be found to

be imperfect, the public interest would be promoted by exposing its fallacy ;

"And Whereas, The Legislature of this Commonwealth reposes confidence in the integrity and qualifications of Henry Voight, Robert Patterson, Nathan Sellers and Oliver Evans, of the City of Philadelphia ; Archibald Binney, Lewis Wermerag and Josiah White, of the County of Philadelphia ; and Samuel D. Ingham, of the County of Bucks :

"*Therefore, Resolved*, By the Senate and House of Representatives, of the Commonwealth of Pennsylvania, in General Assembly met, That Henry Voight, Robert Patterson, Nathan Sellers, Oliver Evans, Archibald Binney, Lewis Wermerag, Josiah White and Samuel D. Ingham be, and they are hereby requested to make a strict examination of the machine invented by Charles Readhefer, and to make specific representation respecting it as its alleged importance and the public expectation require.

"*Resolved*, That the Secretary of the Commonwealth be, and is hereby requested to transmit a copy of the foregoing preamble and resolution to each of the persons named therein, and also to Charles Readhefer."

(Signed.) John Tod,
Speaker of the House of Representatives.
P. C. Lane,
Speaker of the Senate.

In the House of Representatives,
December 14, 1812.
Read and adopted.
Geo. Heckert,
Clerk of the House of Representatives.

In Senate, December 17, 1812.
Read and adopted.
Josiah A. McJimsey,
Clerk of the Senate.

Then follows the certificate of the Deputy Secretary, and his letter to Nathan Sellers. The driving of a supposed motor through machinery which is supposed to be driven by it, is a very general method of deception. Thus, I have seen one of these supposed "motors" set up in a shop and connected by belting and shafting with a number of lathes and other machine tools. When everything was running it was impossible, by mere inspection, to say which may have been the real "driver," since the power might have been transmitted through a hollow journal to any one of a number of points in the system, but you may be quite certain that it is *not* the supposed motor if the conditions of its operation are inconsistent with the doctrine of "conservation of energy." In the case of these fraudulent structures a fortunate accident may aid detection.

About twenty years ago a Mr. Paine had an electro-magnetic engine in Newark, in which many persons whose names are not unknown to fame, and who certainly ought to have known better, "took much stock" in the literal as well as figurative sense. Being in Newark on some other business, I was waited upon by Mr. Paine and invited to see the machine. I accepted the risk (which I will presently explain) attending such a visit, and went with him. The apparatus was shown off with great success, starting with full velocity the moment a connection was made with a little battery of four cells, driving lathes, sawing wood, etc., in a way that demonstrated several horse-power, at least. I need hardly say that I was not convinced that perpetual motion had been discovered, but only looked out for the trick.

Nothing, however, could be demonstrated, without taking the ponderous machinery to pieces. Near the end of my visit, however, in connection with a pseudo explanation of some point, Mr. Paine once more connected the battery, whereupon the machine, in place of starting promptly as before, made a few turns and stopped. This was, of course, accounted for by the inventor as caused by some derangement of parts, but as, a few minutes later, I went downstairs, I looked at my watch and found that it was five minutes after six o'clock. The building at large contained a steam engine, and power was confessedly used in all other parts except those occupied by Mr. Paine. This remarkable failure to

start at just about six o'clock, therefore, revealed the actual source of energy. The little battery, without doubt, operated either a belt shifter in a room below, or signaling a confederate similarly located for a like purpose.

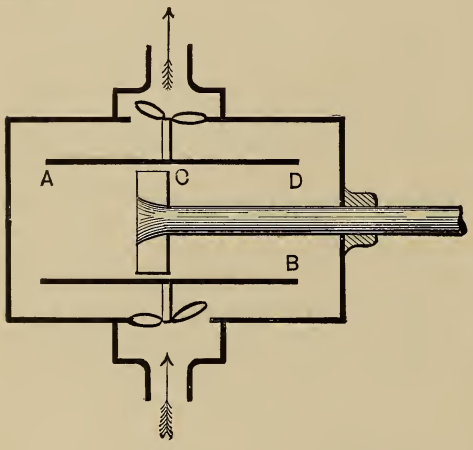
Not long after, Mr. Paine and his electric engine were unsuccessfully sought for by some of his stockholders, and all that was found was a portion of the iron frame of the machine showing an interior passage for a belt to act on its axle from the room below. The connection between the arrival of six o'clock and the stoppage of the motor which I had noticed in my visit, and had, of course, referred to its true cause, was thus fully demonstrated. The risk to which I alluded in connection with such a visit is one of reputation. An ordinary sense of politeness hardly allows one, when visiting a man's workshop on his own invitation, to treat him as if he were a cheat and his statements as falsehoods, even if we so believe them to be; and thus one, from mere politeness, is almost sure to say something which may be quoted by interested parties as an indorsement; and such statements are very difficult to correct and explain, when they have once been put in circulation. It is, therefore, a very good plan, when one is requested to look into such a matter, to decline unless an agreement is made that every interior detail of the machine shall be exposed to your inspection. In nine cases out of ten this will relieve you of any further solicitation. On the other hand, to make any agreement not to reveal what you see, as was asked in some cases, as I know, in connection with the Keely motor, is, of course, what no sensible man would do, as it would make it possible to use his name in support of what he might have detected to be a fraud.

It may seem almost needless to say so much on the subject of these gross and conspicuous fallacies; but, while the stock of the Keely Motor Company, in the face of repeated exposures and years of unfulfilled promises, has to-day a value in the market, and when not only such daily papers as are notorious for their lack of truth, honor or decency, but even respectable journals, will publish articles seriously advocating such plans, it is evident that even such fallacies need to be met and exposed by the intelligent engineer. Besides these fallacies, which involve more or less intentional deception, we encounter others which are the result of perfectly honest, but none the less fatal, mistakes in observation or experiment.

A striking instance of this is furnished by one form of what is known as the aero-steam engine. This was a plan for admitting air into the cylinder of a steam engine at a certain point of the stroke, with a supposed gain in efficiency. A number of experiments were made within my own knowledge with a small engine, or, in fact, model, which seemed to demonstrate conclusively the advantage of this modification. When the air was admitted, everything else remaining the same, the engine made twenty per cent. more revolutions in a minute against the same resistance. This was, in fact, thought to be conclusive as to the advantage of the plan. On further investigation, however, it was found that the boiler supplying the steam engine was so inadequate that it could not fill the cylinder for a rapid stroke, and that thus an exhaust or back pressure occurred at each stroke when the engine was running fast. The admission of air at a certain point relieved this back pressure and actually increased the duty, but even when so increased it was inferior to what it should have been with a well-proportioned boiler. This is, in fact, a type of a large class of fallacies, one or another of which we encounter almost daily. An inefficient or defective machine or process is taken as a standard, and some attachment or modification is made which greatly improves the result, and it is thence assumed that this attachment or modification would be of equal efficiency with machines or processes in their normal condition.

Thus, for example, a plan for blowing steam into the ash-pit of a boiler

furnace was, many years ago, extensively advertised, and very remarkable testimonials were shown as to its actual efficiency. On investigation, it, however, turned out that these cases of success occurred where there was a great want of draught in the furnaces, and any means of increasing it would, therefore, have proved beneficial. The steam blast was, however, a much less efficient way of increasing the draught than any of the well-known methods. Such an example teaches the importance of positive measurements in all cases, and the comparison of results with well-known and established standards.




Another example of a practical result apparently proving an efficiency which did not exist, was brought to my attention, some time since, in connection with a pump which developed a pressure much beyond that which would be estimated by calculation of the force applied on the known area of its piston. It turned out, however, that the piston was so loose that the water passed freely from one side to the other, and thus the pump acted only on the inward stroke, when the piston rod played the part of a plunger whose reduced section, as compared with the piston, accounted for the increased pressure obtained. This condition of affairs was, of course, betrayed by the small amount of water delivered as soon as that was observed.

The conditions in this case are fully illustrated by the accompanying diagram in which A B indicates a pump cylinder with a piston C and piston-rod D, and also inlet and outlet valves and passages as shown. If, now, the piston fitted tightly and was moving toward the left it would force water before it through the upper or outlet valve and draw it in behind through the inlet valve below. If, however, the piston was so loose that the water could pass freely round it, then, clearly, no water would be drawn in and both inlet valves would close, but the piston-rod as it was thrust in would displace its own volume of water and force that amount through the outlet. On the reverse stroke no water would be forced out; both outlet valves would be closed, but enough water would enter to fill the space vacated by the withdrawal of the piston-rod. While the volume of water delivered would be thus immensely reduced, its pressure would be proportionally increased, for the force applied to the piston-rod, in place of being diffused over the entire surface of the piston, would be concentrated on the cross section of the rod. The lesson that this teaches is, that when a result is obtained at variance with established principles, don't look for a new law or a new force, but suspect an error of experiment or derangement of the machine.

Such examples as I have just cited teach us also another lesson, which may be embodied in a very brief maxim, which is this, "Never make two experiments at once." That is, when you are investigating a subject and estimating the effect of this or that modification or improvement, never make two changes at once, for then you may easily assign the new result to the wrong one of the two possible causes. Some remarkable examples of this error were furnished some twelve or fifteen years ago in connection with what then excited no small interest among steam users, namely, the "anti-incrustator." This consisted of a group of small magnets sustained by an insulating support in the steam space of a boiler and connected by a copper

wire with the shell of the boiler at the other end. This was supposed to prevent the formation of scale in the boiler.

If unexceptionable certificates and the testimony of the most reliable witnesses as to practical results could have proved anything, this was thoroughly demonstrated to be an efficient apparatus. For several years it had a most successful career. The stock of the company went up like that of some other more recent companies, and what is more, stayed up, and the anti-incrustators were put into boilers by the thousand. In a few years, however, with wonderful suddenness the anti-incrustator went out of favor and became a matter of history only. To explain each instance of its success in operation would be, of course, impossible, but one prominent one will suffice as an example of a large class. This was brought to my attention at the time by Professor Coleman Sellers, E. D., of Philadelphia, who was one of the few who at that time declined to accept the evidence presented as sufficient to establish a claim itself intrinsically unscientific and improbable.

A friend of Mr. Sellers had tried some of these incrustators on boilers of his own, and, finding that they ceased to form scale, was convinced and took a large interest in the company. In conversation with Mr. Sellers he stated this circumstance, whereupon he was asked :—"Did you not make some other change at the same time?" "None of any account," he replied. "To be sure, while the boiler was opened to put in the anti-incrustator, we took advantage of the opportunity to disconnect the mud drum, and in place of it connect the feed with a disused boiler alongside, which we employed as a feed-water heater." Now let me point out that one of the chief scale producing elements in the Philadelphia water is sulphate of lime, which is less soluble in hot than in cold water. With this fact before you, you will at once see that this gentleman had provided a most admirable "anti-incrustator" in his feed-water heater. Here was a large mass of water so heated as to establish only gentle currents and with a slow circulation by reason of which the water remained in it a considerable time, and could thus deposit the sulphate of lime, as that became insoluble through the rising temperature. The sulphate of lime also, of course, carried down with it other suspended matters, as we all know it will under such conditions. Here was a clear case of trying two experiments at once, and of assigning the result to the wrong cause.

Next to these, which may be called mechanical fallacies, we come to a more refined and abstruse class, which may be described as chemical fallacies. Very many who may be quite able to see that no combination of levers, pulleys, wheels, etc., can make a machine operate itself without external supply of energy, or can convert one horse-power into two, are not able so readily to see why a pound of coal may not be able to produce more than its regular equivalent of heat. One of the forms of this fallacy which is most active at the present day is expressed with charming naivetè in an article which appeared in The Popular Science Monthly for March, 1880, with the title, "Water as Fuel," and also in a paper read before the Engineers' Club of Philadelphia, and published in The American Gas Light Journal of February 16, 1880. The leading fallacy developed in these articles is that involved in the title first quoted, "Water as Fuel." To any one understanding the actual conditions, this title would be even more absurd than such a one as "Ashes as Fuel," "Rest as a Source of Motion," or the like. Water is simply the ashes of a perfect combustion, and is no more capable of becoming fuel than the most perfectly burned ashes from a wood or coal fire.

Fully to realize the true relation of this and other like matters, we must take a rather wide view of our chemical surroundings here as we live on the earth's surface. We are surrounded by a practically unlimited supply of diluted oxygen in the form of the at-

mosphere, and all practical combustion must consist in a union of one or another fuel with this oxygen in the air. While there are hundreds of other chemical combinations capable of producing heat, and which might with great propriety be called combustions, none but those involving the union of some fuel with atmospheric oxygen are practically available, and while from a purely philosophical standpoint it is just as proper to call oxygen the fuel and coal the supporter of combustion, yet in their existing practical relations it is far more convenient and appropriate, and fully as accurate, to look upon atmospheric oxygen as the universal and freely supplied supporter of combustion, and coal, wood, and other materials capable of energetic union with it, as combustibles or fuels. It is these for which we pay, and whose economical consumption is of importance, and the atmospheric oxygen may be safely taken for granted, with only such limitations as to secondary effects of its wasteful use as will, of course, be familiar to all engineers.

Realizing this, it will be evident that the value of any fuel depends primarily upon its capacity of uniting with the oxygen in the air, and that the addition to it of anything which does not possess such a capacity can in no way add to its heat-producing capacity, though, of course, it may render it more convenient of application in certain cases. To illustrate this :—The heat energy in ordinary illuminating gas is by no means greater than that present in the coal from which it was made, but, on the contrary, is vastly less ; yet, nevertheless, its convenience of application renders it actually more economical to apply it to a vast number of uses notwithstanding an immense loss of total heating capacity. What, then, is the true office of water in its relation to fuel properly so called? Simply that of a vehicle, which, at a certain sacrifice of total efficiency, nevertheless, facilitates the application of the heat energy (derived exclusively from the fuel) under certain circumstances.

In numerous cases solid fuel cannot be brought conveniently in contact with the material to be heated, and then it may be desirable, even at a certain loss of total effect, to turn the solid fuel into a gas for the sake of this increased convenience of application and consequent special efficiency. In such cases water may become a useful agency, but you cannot too firmly fix in your minds the fact that its beneficial effects depend solely on this facility of application, and not by any possibility, on any contribution by it to the total energy developed in the combustion of the fuel. The oxygen and hydrogen of the water have already developed in their mutual union all the potential energy they possessed in this relation, and before they can again exhibit any such force it must be supplied to them from some other source, such, for example, as the combustion of actual fuel, and then what they give out again will be exactly what was thus supplied to them and no more.

When, therefore, we encounter such statements as that by the use of water with coal the thermal equivalent of the carbon can be practically raised from a theoretical maximum of 14.300 heat units to a practical efficiency of 18.000 heat units, or that six pounds of carbon whose theoretical maximum is 85.800 heat units, can, by the aid of nine pounds of water, develop 124.000 heat units, let us not mistrust our previous impressions, and fall into doubt as to the truth of the great theory of conservation of energy, but look out sharply for a fallacy in the reasoning which has led to such a conclusion. We should remember, in fact, that while very few things are so improbable that they might not be established by sufficient evidence, yet the amount of evidence must be vastly increased when a seeming result is at variance with established laws, and that we will be well repaid for the closest scrutiny and the utmost deliberation, by the avoidance of disastrous errors.

Another common source of error and consequent loss is the neglect in the consideration of a subject of what may

sometimes seem trifling practical details, but which often control the question of success or failure. Thus, for example, it was seen at quite an early date that a hot air engine was theoretically a more economical motor, if questions of practical detail were neglected, than a steam engine. Immense sums of money and a vast amount of the highest inventive genius have been expended on the development of such engines for general use. The small practical details of excessive bulk in the machinery, consequent friction, the use of very high temperatures, and the like, have, however, limited the application of the air engine to a very narrow field.

In like manner, theoretically considered, the magneto-electric machine, driving its exciting field-of-force from permanent magnets, is manifestly more economical than a dynamo-electric machine whose exciting field-of-force is maintained only by a constant expenditure of active energy. Yet, as a matter of fact, this theoretical economy is more than balanced by the practical impossibility of securing great intensity of magnetic field with permanent magnets, so that the losses caused by the greater friction and electric resistance present in the larger and more complex magneto-machines, are greater than those involved in the constant generation of a magnetic field by the use of an electric current in the dynamo machines.

Some curious fallacies have been presented to the public within the last few years, resulting from a failure to recognize that a horse-power did not express an amount of work but only the rate of doing work. Thus, in order that a horse should develop one horse-power he must raise 33,000 pounds one foot high in each minute of the time he is working, and, thus, if he works for ten minutes he will do the amount of work represented by 330,000 foot pounds, or if he works for ten hours his work will be sixty times as much as that, or 19,800,000 foot pounds. About a year ago a machine was exhibited which may be briefly described as a steam engine employing liquefied ammonia in place of steam, and in exhibiting it, its promoters caused it to raise 33,000 pounds one foot high in ten minutes, and reckoning this as a horse-power machine showed a remarkable economy as compared with an ordinary one horse-power steam engine. None of the promoters or unprofessional spectators seemed to notice the fallacy or to realize that if this engine and an ordinary one horse steam engine had been working side by side, sawing wood for example, the steam engine would have done as much work or sawed as much wood in each minute as the ammonia engine did in ten minutes, and that thus at the end of the day the work or wood pile of the steam engine would be ten times larger than that of the ammonia engine. In fact the ammonia engine was not a one horse-power machine but a one-tenth horse-power machine.

This incident brings to mind another error which sometimes causes curious mistakes in connection with this same measure of the rate of doing work, *i. e.*, the horse-power. The standard horse-power, 33,000 foot pounds per minute, does not mean all that a horse can do, but what he can keep up steadily for eight hours a day. In starting a heavy load or in jumping or running, a horse can develop work for a few minutes at a rate many times as great as this. The same is true of a man. Doing steady work hour after hour a man can develop about from one-tenth to one-fifth of a horse-power, according to circumstances, but under the most favorable conditions an ordinarily strong man can develop work for from fifteen seconds to a minute at the rate of a horse-power. This is on record in "A treatise on the construction of cranes," by J. Glynn, Crosby Lockwood & Co., London, 1880, but is not, I think, generally known.

My attention was first called to it in the following way :—I was asked to test a dynamo machine for which the claim was made that it was many times as efficient as the best Brush or Weston dynamos. I suggested that this was not possible because the above-named

machines had efficiencies of between 80 per cent. and 90 per cent of a theoretical maximum. The reply to this consisted in the following questions and answers:—Q. How much power does an ordinary Brush arc light require? A. About one horse-power. Q. How does a man-power compare with a horse-power? A. As about 1-5 to 1-10 to one. Q. If then one man, with a dynamo under discussion, can run one Brush arc light, will not that prove the machine to be from five to ten times as efficient as a Brush dynamo?

To this I replied that I would like to see it done. In due time there came to hand a large fly-wheel mounted on a frame with a pulley for belting to the dynamo and a winch to turn it by. All being arranged it was found that a strong man could in fact keep up an arc light with this apparatus for about fifty seconds. As soon as this was demonstrated, a dynamometer was attached in place of the dynamo, and this showed that in the same way the same man could develop about one horse-power for the same time. I was curious also to observe how completely a man of ordinary strength was exhausted in this or a shorter time when expending energy at this high rate. Experiments narrated in the work above named showed that men practiced in turning a winch could keep up such work for from two to three minutes.

This matter of the true measure of a horse-power frequently comes in as an important practical question. Thus in considering motors for street cars, it does not at all follow that a two-horse steam engine or other motor could practically replace a pair of horses. The two-horse engine could exert no more power in starting the car than at any other time, while the pair of horses could, for a few moments, work at the rate of eight or ten horse-power and so accomplish all that was needed when the engine would fail.

There are certain erroneous impressions as to the true relations of force, energy and work, originally derived from our personal sensations which are constantly encountered. Thus, in connection with the early so-called "demonstrations" of Mr. Keely there was a constant confusion of "pressure" (which is an example of "force" with "work" or its source "energy") and the public was constantly told that Mr. Keely had discovered a new and vast power capable of accomplishing vast results in the way of work because he showed pressures of thousands of pounds on gauges. If one holds up a weight in the extended hand he is soon as tired as if he had done a considerable amount of work, and it is therefore natural to feel that the mere exercise of force is equivalent to the doing of work. Work, however, is a compound entity involving not only the exercise of force, but also the accomplishment of motion. A force of one pound acting by causing motion through one foot will do the work of a foot pound; but a force of a million pounds not moving or causing motion through any distance will do no work. Work must always be a product of force and distance moved. A realization of this will save us from the fallacies involved in schemes for the development of "power" from such forces as the expansion of solids or liquids which though enormous in their intensities are limited to insignificant distances in their range of motion. The same principle applies to many proposed forms of magnetic motors, where the intensity of an attractive force is offset by the shortness of its range.

Another instance of an erroneous impression arising in the same way is the very common one that the reaction of an escaping jet upon the vessel from which it flows depends in some way on the exterior resistance of said jet. If we stood at the stern of a boat and wished to push the same forward we could accomplish much more by placing a pole against the shore or some firm obstruction and pushing than if we had no such resistance to act upon, and, therefore, we feel that if we are trying to propel a boat by driving a jet of water from her stern a better effect will be secured in proportion as

the jet strikes against a more and more unyielding resistance. In fact, however, the energy expended, or work done, in so propelling a boat depends solely on the energy or work involved in the ejected jet, and is exactly the same whether the jet is thrown above the water level into the air, below the level into the water or in some other arrangement into a vacuum. A failure to appreciate this well established fact involved within a few years the useless expenditure of a large sum in attempting to drive a boat by water jets expelled at high velocities, under the impression that the greater resistance to the jet after it had left the nozzle, secured by its high velocity, would produce a beneficial effect upon its "reaction" or power to drive the boat.

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# THE TEMPERATURE CYCLE IN A CYLINDER WALL.

*By E. Thos. Adams.*

EACH generation of engineers since the days of James Watt has wrestled with the problem, "How shall we keep the wall of the cylinder as hot as the steam which enters it?" Watt, unaided, solved his problem in part, more than a century ago, and each decade since has seen some notable advances toward its final solution; yet the engineer of to-day is still repeating the same question without finding a wholly satisfactory answer. True, we do not, as when Watt stated the problem, waste three-fourths of the steam entering the cylinder; but the loss due to initial condensation is still the greatest thermodynamic loss in the steam engine.

Watt determined the amount of this loss by comparing the volume of the cylinder with the volume of steam required to fill it during each stroke of the engine. Modern engineers, using essentially the same method, have shown that the amount of condensation varies with the speed of rotation, the ratio of expansion, and, in an unknown manner, with the condition of the interior surface of the cylinder. With this much accomplished, it would seem that it was only necessary to take the recorded results of the hundreds of careful experiments that have been made and deduce from them the coveted expression. Unfortunately these results are not comparable, partly because, in too many cases, that which is reported as cylinder condensation is really condensation plus leakage of unknown amount; and partly for the reason that the investigations have been made with engines varying in the form, finish, and lubrication of their cylinders, and while condensation varies with the number of revolutions and ratio of expansion, it also varies, perhaps to a far greater degree than is usually imagined, with these minor variables which are constantly neglected.

It is practically impossible to determine the effect of these minor variables in the usual manner, for, while measurement of the condensation may give the loss, it does not give the distribution of the waste, which is what we should know in order to prevent it. However, the heat lost by the steam is given up to the iron, and if we can measure the heat transfers taking place within the cylinder wall, we have the means of determining how initial condensation varies with the form, finish, and lubrication of the cylinder and have advanced a step toward the final solution of a much-vexed problem. With this object in view, an experimental study was made of the heat transfers occurring within the metal

wall of an engine operated under usual conditions. This paper simply records the results of these experiments, leaving their bearing on the broader subject of initial condensation for discussion after further research shall have given adequate data from which to draw accurate conclusions.

Heat energy is the most elusive quantity with which the engineer has to deal. The heat changes within the iron take place with wonderful rapidity, and there is great practical difficulty in obtaining a measure of the heat transfers at any point without changing normal conditions. Still, these difficulties have been overcome by an electric photographic method which gives a card indicating changes in the temperature at a given point in the cylinder wall during the movement of the engine piston, just as the ordinary indicator card gives the changes in temperature of the steam with reference to the same base. Fig. 1 is a card, reproduced from the original negative, showing the temperature changes at a point $\frac{1}{100}$ inch below the inner surface of the cylinder head. The irregularities at the end were made when the cover of the photographic plate-holder was removed.

Each part of the cylinder wall has its characteristic card, the area of which is, roughly, proportional to the condensation loss due to that portion of the cylinder. There are two classes of these cards. The surfaces swept over by the piston during a cycle of the engine have two heat cycles per revolution and form one class, while the parts not passed over by the piston have but one cycle, forming the second class.

FIG. 1. CARD REPRODUCED FROM ORIGINAL NEGATIVE, SHOWING TEMPERATURE CHANGES IN A CYLINDER WALL.

The cards here shown belong to the latter, and represent the conditions existing in the portions of the cylinder wall which, since they are exposed for the longest time to the maximum range of temperature, evidently have the greatest influence on cylinder condensation.

This affords another proof of the importance of jacketing or properly protecting the cylinder heads, and of making port passages as short as possible. There seems to be no mechanical reason why a non-conducting coating of some sort should not be applied to the piston head and the ends of the piston, as has long been urged by various

writers. The fact that these cards give an easily applied method of finding the exact effect of such a coating will doubtless give new life to investigations in this line. Dr. R. H. Thurston has long recommended finely finished interior surfaces bathed in oil as a simple and effective method of reducing the condensation loss.

Figure 2 shows the effect of oil in reducing the rate of heat transmission from the steam to the cylinder wall. An engine running with a semi-occasional injection of oil, but depending for lubrication mainly on that water of condensation which is so often asserted

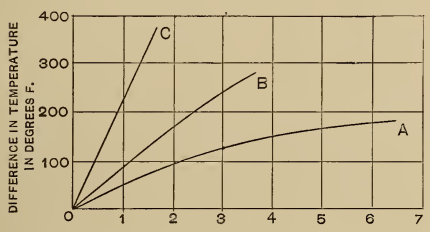


FIG. 2. DIAGRAM SHOWING RATE OF HEAT TRANSMISSION IN B. T. U. PER SQUARE FT. PER MINUTE PER DEGREE DIFFERENCE IN TEMPERATURE.

A—From Steam to Cast-iron.
B—From Steam to Cast-iron Having an Oily Surface.
C—From Oil to Cast-iron.

to be good for that purpose, would give a rate approximating to that in curve A. This gives the rate of heat transmission from steam to clean cast iron for differences in temperature, between the steam and the iron, up to 200 degrees Fahrenheit. Curve B shows the rate for a well-lubricated cylinder. Curve C gives the rate from oil to cast iron, and would probably be closely approximated if Dr. Thurston's suggestion should be carried out. The wide divergence of curves A and C suggests that the effect of more thorough lubrication of the cylinder of the steam engine is worthy of investigation on account of its influence on cylinder condensation as well as on engine friction.

Figure 3 shows the temperature cards for the steam and for the iron cylinder wall. The cards were taken simultaneously from a simple condensing engine having a fixed eccentric. The steam pressure was fifty pounds, and the number of revolutions, forty per

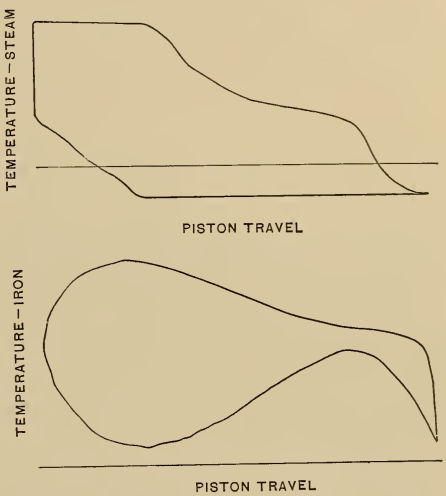


FIG. 3. TEMPERATURE CARDS FOR STEAM AND CYLINDER WALL.

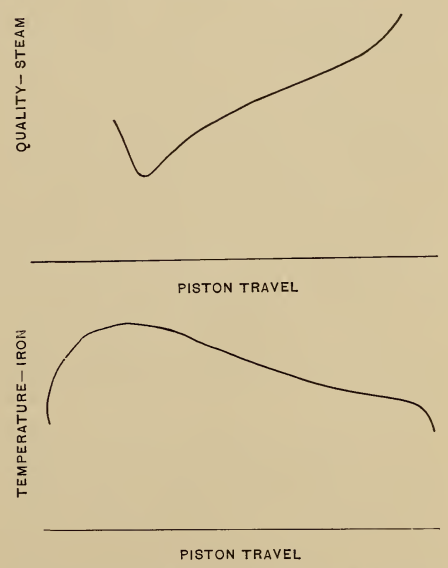


FIG. 4. COMPARISON OF QUALITY OF STEAM AND TEMPERATURE OF CYLINDER WALL DURING FORWARD STROKE OF ENGINE.

minute. The steam temperature card is the ordinary indicator card. The iron temperature card was obtained as follows :—A thermo-couple was so arranged that it did not obstruct the free

flow of heat in and out of the cylinder wall. The temperature of the cold junction of the couple was kept constant. The current flowing was thus proportional to the temperature at the hot-junction, and caused galvanometer deflections, which were also proportional to the temperature at the same point.

A ray of light was thrown upon the galvanometer mirror, from which it was reflected to a sensitive plate. By a suitable connection with the reducing motion, used for the indicators, this plate was moved in a plane perpendicular to the plane traversed by the light ray reflected from the galvanometer. The resulting curve, photographed on the plate, is reproduced in Fig. 1 and in Fig. 3, and is compared with the indicator card taken at the same time.

Following "clock-wise" about both cards, we find a rise in temperature during admission, a gradual fall during the expansion period, and a sudden drop when the exhaust port is fully open. During the early part of the return stroke there is a rise in temperature at the hot-junction of the thermo-couple. This is due to the reheating of the surface by heat flowing from the interior of the cylinder wall. This rise reaches a maximum when the temperature at the surface approximates that within the mass, after which the temperature gradually falls as the heat is radiated from the cylinder wall. The rise to the point of beginning is caused by the heat generated by the work done on the steam during compression.

At the end of expansion we have within the cylinder a considerable amount of water; when the exhaust port is opened, there is a sudden fall in both temperature and pressure of the steam. The heat transmission then is from iron to water with a great difference in temperature. The great and practically instantaneous fall in the temperature of the interior surface of the cylinder wall shows how rapidly, under these conditions, the iron gives up its heat to the water. The subsequent reheating of this surface proves that the flow of heat to the water has been more rapid than through the mass of iron itself.

After the water has boiled off and gone its way to the condenser, the heat transmission is from iron to a vapor, and takes place at a less rapid rate. This is shown by the rise in temperature at the hot-junction, the rate of heat transmission through the iron now being greater than that from the iron to the vapor within the cylinder. Of course, the changes in the temperature gradient also contribute to this effect. The action at this point is exactly that which occurs when a bar of iron, heated to a red heat, is plunged for an instant into water and is then held in the air. When the bar is first withdrawn from the water, its surface appears dark, changing again to a red after a short time. That is, when the bar was in the water the surface was suddenly cooled, but when withdrawn from the water and held in the air, to which the iron gives up its heat more slowly, the surface is reheated by heat flowing from the interior of the mass.

The heat lost by the steam is taken up by the iron; hence, if we plot a curve, showing the quality of the steam at different points in the stroke, we would expect this curve to be just the reverse of the temperature curve for the iron during the admission and expansion periods. Those curves, shown in Fig. 4, bring this point out very clearly.

To meet the demands of each important industry, a special type of engine has been developed—a type in which the conflicting efficiencies, mechanical and financial, have been nicely balanced. The practical question of to-day is, "How shall we improve these present types of engine?" It is along this line, using the apparatus herein described, that further experimental work is being carried on at Sibley College, Cornell University. The work so far done simply adds another proof of the importance of arranging the ports to properly drain the cylinders, and of using every means possible of clearing them of water.

# JOHN ERICSSON, THE ENGINEER.

JULY 31, 1803—MARCH 8, 1889.

*By William Conant Church.*

(Concluded from page 176.)

IN 1843 Ericsson's representative in England, Count von Rosen, received orders to fit up the Pomone, a French 44-gun frigate, with Ericsson's propeller and engines below the water line, and this example was followed the next year (1844) by the dilatory British Admiralty, in an order given to Von Rosen for the Amphion frigate, Ericsson furnishing the general plans for the vessel, from this country. Bourne, in his standard "Treatise on the Screw Propeller" (1852), tells us that the engines of these vessels were the first engines in Europe which were kept below the water line; the first direct-acting horizontal engines employed to give motion to the screw, and that Ericsson's was the first example of a screw vessel's being employed for commercial purposes." "Ericsson," he says, "threw the dogmas of the engineers to the winds, and coupled the engine immediately to the propeller."

During their discussions of naval matters in England, Erricsson had presented to Stockton and Ogden his ideas on the subject of ordnance. Wrought-iron was used in the earliest years, but, as sizes increased, cast-iron was resorted to. Recent successful attempts at forging large shafts in England had satisfied him, and he succeeded in satisfying Stockton that heavy guns could be forged. So a wrought-iron gun of the then enormous calibre of twelve inches was forged in England, after designs made by Erricsson, as early as 1834. This he brought with him when he came to this country. It was tested at Sandy Hook against a target of four and a half inches, then and so long after considered impregnable, and sent a shot clean through it and far into the bank behind. The gun was sighted by its designer, who was an expert artillerist, and had been known as early as 1820 as a skilled artillery draughtsman. He was familiar, too, with the construction and manipulation of the Swedish 80-pounders employed in the Baltic boats, when nothing beyond a 40-pounder was known in the American Navy.

This 12-inch gun proved too weak, and it was strengthened with bands, as is now the general custom in building heavy guns. These bands were two and three-sevenths inches in depth by nine inches in width, and the four were placed contiguous to each other, and so neatly finished that in appearance they formed a single band. The plan proved entirely successful, and after further tests the gun was put on board the Princeton. To it were applied Ericsson's self-acting lock and his gun-carriage, which made it possible to fire heavy guns at sea by effectually taking up the recoil. The Princeton was also furnished with the instrument for measuring distances, for which the London Exposition in 1852 awarded a medal.

Stockton also ordered a gun in this country on the model of the one brought from England, but a foot larger in diameter at the breech, and thus much heavier. This is the gun called the Peacemaker, which burst while a distinguished party was visiting the Prince-

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ton at Washington, February 28, 1844, killing the Secretary of State, Mr. Upshur, and the Secretary of the Navy, T. W. Gilman; Colonel Gardiner of Gardiner's Island (off Long Island), and four other visitors, besides desperately wounding several of the vessel's crew. Ericsson's first gun stood the severest possible tests, and was subsequently fired one hundred and fifty times with heavy charges, in the vain attempt to burst it. It is now at the Brooklyn Navy Yard with the target it pierced. Ericsson had more confidence in his gun called the Oregon, and urged Stockton to fire that when exhibiting his vessel, instead of the Peacemaker. This advice was not accepted; but when the disastrous result followed Stockton wished Ericsson to take the responsibility for the gun. As he had been most unhandsomely deprived of the credit which belonged to him for his work upon the Princeton, he refused to be thus made a scapegoat of, and a breach in their friendship followed.

"The triumphs of genius," says Dr. Dionysius Lardner, in his "Popular Lectures on Science and Art" (1846), "are not unattended with alloy. The moment that any invention proves to be successful in practice, a swarm of vermin are fostered into being to devour the legitimate profits of the inventor, and to rob genius of its fair reward. Captain Ericsson, so long as his submerged propeller retained the character of a mere experiment, was left in undisturbed possession of it; but when it forced its way into extensive practical use—when it was adopted in the United States Navy and in the Revenue Service—when the coast of this country witnessed its application in numerous commercial vessels—when it was known that in France and England its adoption was decided upon—then the discovery was made for the first time that this invention of Captain Ericsson's was no invention at all—that it had been applied since the earliest dates in steam navigation. Old patents—some of which had been still-born, and others which had been for years dead and buried—were dug from their graves, and their dust brought into courts of law to overturn this invention, and wrest from Captain Ericsson his justly earned reward."

During the years immediately succeeding the Princeton experience Ericsson was occupied in introducing his propeller and defending his rights of property in the courts at great expense. Meanwhile he devoted such attention as he could to his caloric engine. He never ceased to believe in his pet, and later on, in the midst of his Monitor triumphs, he wrote: "The satisfaction with which I place my head on the pillow at night, conscious of having, through my little caloric engine, conferred a great boon on mankind—though the full importance of that boon may not be understood until the lapse of perhaps another century—is far greater than any satisfaction the production of an engine of war can give. The steam engine uses water, which prevents its employment in millions of cases requiring motors to relieve human drudgery. We cannot trust that dangerous agent to the care of our wives and children, but the caloric engine we safely may. We can turn the key to the room containing it, and the humble artisan may, without apprehension, ply his tool while this harmless servant turns the crank and cooks his food."

Of this little caloric engine thousands have been sold, and many thousands more of the hot-air engine that succeeded it. This last still continues in extensive use, requiring a large establishment for its manufacture and sale. The patents for these inventions Ericsson gave to business associates to whom he was indebted for favors and assistance in carrying on his experiments.

In the attempt to apply the caloric principle upon a larger scale Ericsson failed; yet this failure was accompanied by a display of engineering capacity which would have transformed it into a triumph for most men. The fact that he succeeded in procuring half a million dollars to build the caloric vessel bearing his name, illustrates his influence with men of capital and conservative temperaments. He was an eloquent talker upon

any subject in which he was warmly interested—"all fire and flame," as one of his countrymen described him. He was a member of and a frequent visitor to the Union Club in New York. Discoursing there one night on the subject of a caloric ship, Francis B. Cutting, the eminent patent lawyer, who was present, declared emphatically "that if Ericsson was sure of producing a speed of five miles an hour, he ought not to hesitate," reminding him of Fulton and his first attempt.

Thus encouraged he determined to proceed with his plans. Mr. Edward Dunham, late president of the Corn Exchange Bank, Mr. John B. Kitching, and other men then well known in commercial circles, furnished the money to build a vessel of two thousand tons, with caloric engines costing $130,000, and having cylinders of one hundred and sixty-eight inches in diameter and six feet stroke. Work upon her was pushed with her designer's accustomed energy, and her machinery was in motion within seven months from the date of laying the keel—a feat unrivaled, considering the enormous mass of the machinery and its novel features. The vessel on an experimental trip to Washington and Richmond registered a speed of eight miles an hour, and even attained a speed of eleven miles—three miles in excess of Mr. Cutting's limit. But the inherent vice of hot air as a motor revealed itself in a most unmanageable form when it was attempted to apply it on this colossal scale. Ericsson found, as did his rival, Rev. Dr. Stirling, of Dundee, Scotland, that the high heat required affected the shape of the cylinders, causing leakage, and burned out the lubricants with which the joints were tightened. The temperature of a hot-air engine, it must be remembered, is necessarily twice that of ordinary steam.

In a commercial sense, the Ericsson was unsuccessful, and yet it was one of the greatest mechanical triumphs of the period. No better specimen of workmanship than her huge engines had then been produced by American artisans in American workshops. With steam substituted for caloric, the vessel carried the Seventh New York Regiment, in 1858, to Richmond, as escort to the body of President Monroe; was used as a transport vessel during the civil war; and finally, in her old age, was transformed into a sailing vessel, carrying coal.

Ericsson was defeated but not discouraged. Nothing better illustrates his energy, his force of character, and his unfailing confidence in his own mechanical conceptions than the fact that he still continued his labors upon his caloric engine. He insisted that it was "a boon to humanity, and another step in the progress of man ordained of God." Nor did he lose the confidence of his friends. Twenty or thirty thousand dollars more were expended on experimental engines, and improvements were patented in 1851, 1855, 1856, 1858 and 1860. He was compelled now to work on what the artists call "pot-boilers," and lay aside his grander schemes for some more fitting season, a season never to come. In a letter to the associates in his earlier enterprise he gave expression to the painful disappointment he experienced in being obliged to limit his ambition. He declared his most emphatic belief that the system of motive power he was at work upon would some day be perfected, and asserted that ten per cent. of the $500,000 expended upon the caloric ship, devoted to further experiments, would produce great results. He had given up his time for four years, and incurred personal liabilities amounting to $30,000 in attempting to show "that bundles of wires are capable of exerting more force than shiploads of coal," and he could go no further.

These "bundles of wires" were what Ericsson called his "regenerator," an apparatus consisting of masses of wire netting so arranged as to extract the heat from the air passing out, after having done its work, and transfer it to the cold air coming in to complete the circuit. Sir William Siemens, who afterward made effective use of this principle in his regenerative furnace, declared that it failed in the hot-air engines for want of proper application; and there

can be little doubt that Ericsson would have conquered the difficulties he encountered could he have continued his experiments. Sir William further insisted, in his address before the British Association, in August, 1882, that "the gas or caloric engine combines the conditions most favorable to the attainment of maximum results, and it may reasonably be supposed that the difficulties still in the way of their application on a large scale will gradually be removed."

This was Ericsson's belief, and it was with a heavy heart that he abandoned further experiment, and devoted himself to perfecting his early engine of a simpler device, which could be made available at once, even if its possibilities were less brilliant. "I find myself on the verge of ruin," he wrote, "and I must do something to obtain bread, and vindicate to some extent my assumed position as the opponent of steam." This was in 1855, and during the six years intervening between that time and our civil war he had redeemed his fortunes and was in receipt of the handsome income of which long before he would have been in possession had he been content to let the future take care of itself, so far as the solution of mechanical problems is concerned.

One motive prompting Ericsson's labors on the caloric engine is explained in a letter he wrote to The London Times in 1860. "The close observer of labor-saving machines is well aware," he said, "that of late years the legitimate bounds have been passed, and that we are rapidly encountering the danger of intellect-saving machines by introducing mechanical devices for effecting everything which has hitherto been the result of the combination of intellect and muscular effort. It is needless to speculate as to the effect upon our race which this dispensing with intellect and the substitution of monotonous muscular labor will produce in time. The evil is manifest."

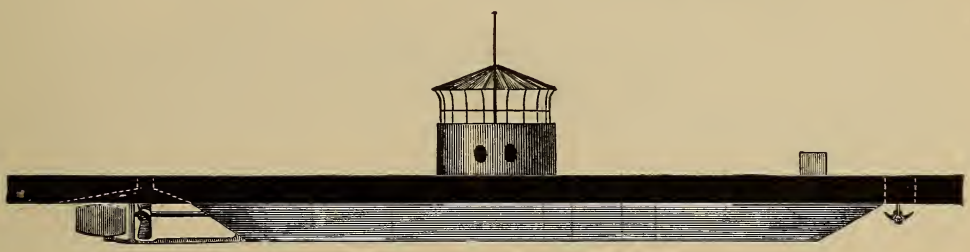
This is only one of numerous contributions to the periodical press, for Ericsson wrote with clearness and force upon subjects in which he was interested, and his articles were always welcome. On one occasion he sent a contribution to a leading New York newspaper. Its appearance was so long delayed that he concluded that it was not wanted, and sent a copy to another paper. The next day the two contributions were published as editorials, and for once papers that could by no possibility agree were found in perfect accord, not only as to ideas, but as to the language in which they found expression. Amusing explanations from these papers and some good-natured gibing from their rivals was the result; the occasion being unusually favorable for a display of that amiable solicitude concerning the mistakes of contemporaries which is characteristic of the press.

Ericsson's relations to the U. S. Government were not confined to his work upon the Princeton. His services and his inventions were in request for the transport vessels of the Quartermaster's Department of the Army during the war with Mexico and for the Revenue Marine vessels of the Treasury Department, as well as for the Navy. Necessity compelled him to realize some of his most brilliant conceptions through the favor of the Government, if at all. He seems to have seen from the beginning, more clearly than anyone else, that the introduction of steam-power called for a complete reconstruction of navies, instead of a mere adaptation of the existing establishments to new necessities. He comprehended with equal clearness the conditions essential to the use of armor as a means of protecting naval vessels from the destructive fire of shell. Hence the two distinct epochs of change marking the progress of naval science during the quarter century from 1840 to 1865 dated, one from the appearance of his Princeton in 1843, the other from the advent of his Monitor in 1862. The idea of a submerged turreted vessel was the result of studies leading naturally and inevitably to the absolute discarding of sails in favor of engines, and the substitution of "steamanship" for seamanship. It was an idea against which nautical prejudice was naturally arrayed, for it put an end to the

romance of the sea, replacing the trim sailor with the grimy stoker, and destroying the charm of a life upon the ocean wave.

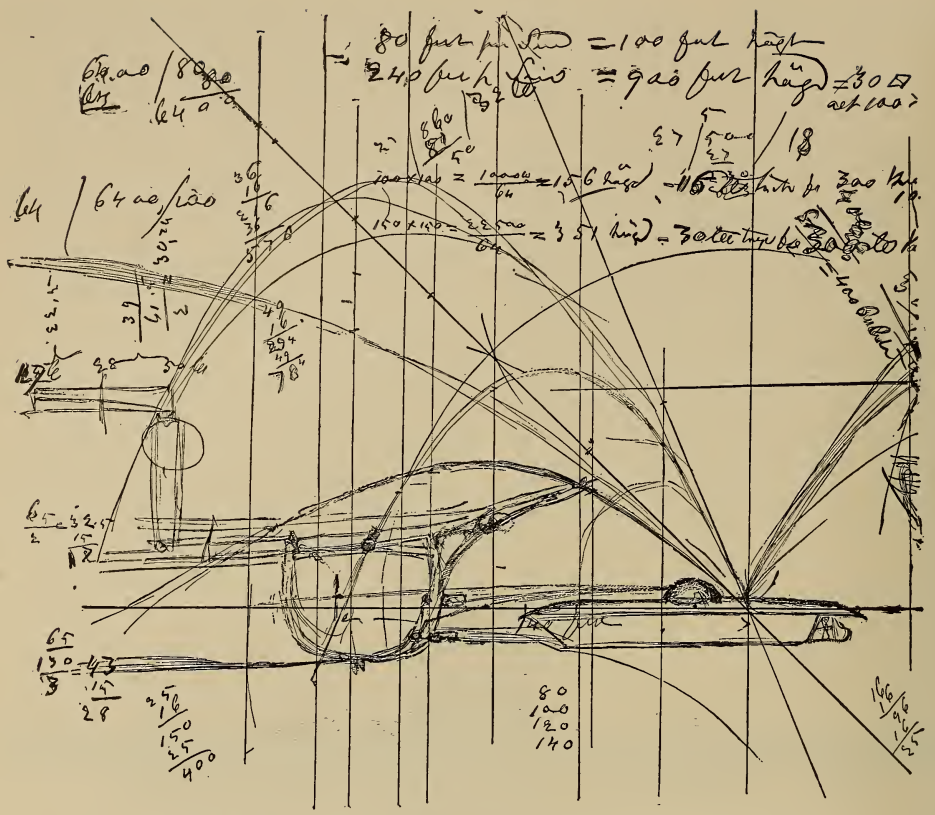
"Do you not know," wrote Ericsson, "that you can never convince a sailor?" As someone else has said, "Sailors is the most fashionablest folks there is." Forty years, or the period of Israelitish wandering in the wilderness, is supposed to be required for the complete acceptance of a new idea. Another generation must first succeed, and the old be buried, and its prejudices with it. This period of probation will not have passed before there is a general recognition of the force of the arguments which led logically to the Monitor as the most efficient type of armor-clad—"the safest, stanchest and most formidable vessels in the world," as one of our naval officers, Commander J. J. Brice, has recently declared. Millions have been spent in the vain attempt to improve upon it, and its critics fail to recognize the unities of the design and disregard its inventor's most positive declaration, that the turret system and the Monitor system must go together; that a Monitor without a turret or a turret without a Monitor is worthless. The plan of putting turrets upon vessels with sides rising fourteen or fifteen feet above the water is, Ericsson said, simply ridiculous. Officials who plan such structures show gross ignorance of first principles.

The contest between the Monitor and the Merrimac was a fair test of the relative value of Ericsson's theory and the theories which have been so persistently opposed to it. Now from one of our sailors comes the declaration, equally frank and truthful, that "there is no doubt, if improved vessels of to-day, representing the respective types, became engaged in battle, the effect in its results would be a repetition of the first fight." "Contenting ourselves with looking idly on at ship-building," says Commander Brice, "speculating upon the success of the magnificent vessels yearly launched in Europe, we are to take advantage of these improvements, so we are told, and thus make ready to seize upon the right thing, when it has been discovered, at the expense of someone else. What should be our mortification now in seeing the tendency of European construction drift into the Monitor system, whilst we, who having been parading our shrewdness in profiting by others' experience, have failed to comprehend that we held in our hands what the world has been seeking."



THE ORIGINAL MONITOR.

The Monitor was part of what Ericsson called his system of subaquatic attack. This was in his mind from his youth up, and strongly presented itself to his imagination in 1826, the year in which he had the conversation with Count von Rosen heretofore referred to. "An impregnable and partially submerged instrument for destroying ships of war has been one of the hobbies of my life," he said. "I had the plan matured long before I left England (1839). As to protecting war engines for naval purposes with iron, the idea is as old as my recollection." It was not until the American Civil War offered such an exceptional opportunity for



FACSIMILE OF ERICSSON'S ORIGINAL PENCIL DRAWING OF HIS MONITOR, 1854.

overcoming prejudice with the crushing weight of public opinion that he was able, however, to secure attention to these plans of his.

Meantime he had advanced step by step, as occasion permitted, to the development of his scheme. Every stage of progress had thus become familiar to him, and therefore when all others doubted or denied, he did not for one moment hesitate. His experiments of 1842 had shown him, what no one else seemed to know, and what the English had not discovered when Fort Sumter was fired on, that four and one-half inches of armor would not stop a projectile such as that fired from the Princeton gun. His superiority to all others in naval engineering was, at the time he undertook his work upon the Monitor, so marked that the soberest statement of the facts appear like extravagant assumption. We have seen what he accomplished with the Princeton in 1842; during the twenty years following he had unusual opportunities for extending his experience, his judgment matured, and he lost nothing of his capacity for rapid and effective work.

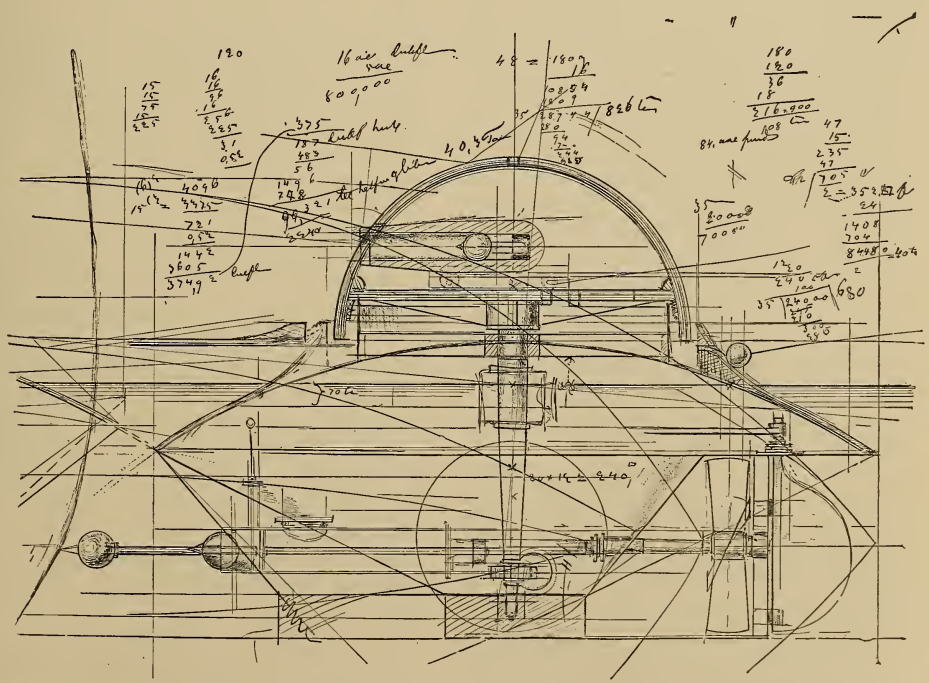
These facts were known, or should have been known, at Washington in 1862. Yet the suggestions of the man who had shown such capacity to deal with the problems of naval warfare were not only not invited, but they were at first treated with disdain. "Take the thing home," said a member of the naval board on armor-clads when the model of the Monitor was shown to him, "and worship it; in so doing you will violate no law, for it resembles nothing that is in heaven above, or that is in the earth beneath, or that is in the waters under the earth."

Before this, Ericsson had written—in August, 1861—to President Lincoln, proposing to build a vessel for the destruction of the Confederate fleet at Norfolk, and "for scouring the Southern rivers and inlets of all craft protected by rebel batteries." In this letter he called attention to the experience which had fitted him for the work, and declared that he sought no private advantage or emolument, as his caloric engine gave him "ample income and the prospect of affluence." "Attachment to the Union alone impels me," he said to Mr. Lincoln, "to offer my services at this fearful crisis—my life, if need be—in the great cause which Providence has called you to defend."

Stephen R. Mallory, who was Ericsson's champion in the Senate in the matter of the Princeton, was at this time Confederate Secretary of the Navy. He was familiar with Ericsson's work, and had a profound respect for his abilities, of which he had learned much in his capacity as chairman of the naval committee of the Senate. Had Ericsson's fortune led him south of Mason and Dixon's line his services would without doubt have been called for, as the Confederates were prompt to recognize the value of armor-clads. While they were making use of their meagre resources to provide them, the authorities at Washington appear to have been in the state of mind of

> "The great Bomfogus, who of old,
> Wore his legs bare, and died of cold,"

because he could not decide which extremity should be first incased in his breeches. They did not know whether they wanted armored vessels or not, and in an official report, more creditable to their frankness than to their knowledge, they confessed, with charming *naïveté*, their ignorance of the whole subject. Some counseled one thing and some another. In the midst of this confusion of tongues Ericsson presented himself. His overmastering presence for the time silenced contention, but no sooner was his back turned than the old doubts and fears revived.



FACSIMILE OF A PENCIL SKETCH BY ERICSSON, GIVING A TRANSVERSE SECTION OF HIS ORIGINAL MONITOR PLAN WITH A LONGITUDINAL SECTION DRAWN OVER IT.

A long series of letters from the naval bureau shows how he was badgered and worried, while he was straining every nerve upon the seemingly impossible task of completing his first Monitor in one hundred days.*

One of two courses was logically admissible: to reject his scheme, or, accepting it, to give him the fullest encouragement in carrying it out at the risk and expense of the government, which had the paramount interest in it. Neither course was followed. The American navy had once been revolutionized at Ericsson's expense; it seems to have been thought that his brains might properly be made use of to any extent without rewarding him with so much as a snuff-box, or one of those decorations so freely bestowed by foreign potentates on those who serve them. The bargain for the construction of the Monitor, forced upon him and his associates by the officials at Washington, would have disgraced Shylock. They speculated, not in his flesh and blood, but in his enthusiasms. It was impossible for him to refuse an offer, however ungenerous, giving him the hope of realizing his grand conceptions. As it was, nothing but a dramatic success, to which fortune in no small measure contributed, prevented the enforcement of the threat, often repeated, that if the new vessel did not successfully pass through that most trying of all ordeals, naval criticism, it would be thrown back upon the hands of its constructor.

Fortunately, criticism was for a time silenced by the circumstances of that world-famous battle in Hampton Roads, on the 9th of March, 1862. The unequal contest of the first day crowned the American navy with a halo of undying glory; but it showed, at the same time, at what a price naval experience has been bought, as it must be bought again. The gallant old sailor, Commodore Smith, under whose directions Ericsson had built his vessel, and whose son was killed in this engagement, was called out of church in Washington, by Secretary Welles, on the day of the Monitor and Merrimac fight, and told that the Congress, commanded by his son, Lieutenant Joseph B. Smith, had surrendered to the enemy at Hampton Roads the day before. "Then Joe is dead," was the father's instant response. He knew his son, and he knew how fully he, like others of the class to which he belonged, could be depended upon to maintain the noblest traditions of a noble service.

All that gallantry and self-devotion could do had been done, but in vain. "The Confederate fleet," says the historian of "The Confederate States Navy" (J. Thomas Scharf), "steamed proudly and triumphantly back to its anchorage, having sent a thrill of joyful enthusiasm through the length and breadth of the Confederate States, dismay and disgrace all over the United States, and revolutionized naval construction throughout the world. From that anchorage, and by the blaze of the burning Congress, the crews of the Confederate vessels saw waving from the masts of the sunken Cumberland the flag of the United States, and heard the booming of the guns of the burning Congress, until the magazine exploding scattered over the water of the Roads the fragments of the frigate; the stranded Minnesota lying riddled; the Roanoke, St. Lawrence, Mystic and other gunboats lying huddled under the guns of Fortress Monroe, and no flag but the stars and bars waving in defiance over all the waters of the Hampton Roads."

The success of the Monitor, on the day following the conflict here described, only partially redeemed the disasters of

*In a confidential letter, written March 23, 1866, Ericsson said: "The great importance of what I call the subaquatic system of naval warfare strongly presented itself to my mind in 1826; yet I have not during this long interval communicated my ideas to a single person, excepting Emperor Napoleon III. What I knew twelve years ago, he knows, with regard to the general result of my labors, but the details remain a secret with me. The Monitor of 1856 was the *visible* part of my system, and its grand features were excluded from its published drawings and descriptions."

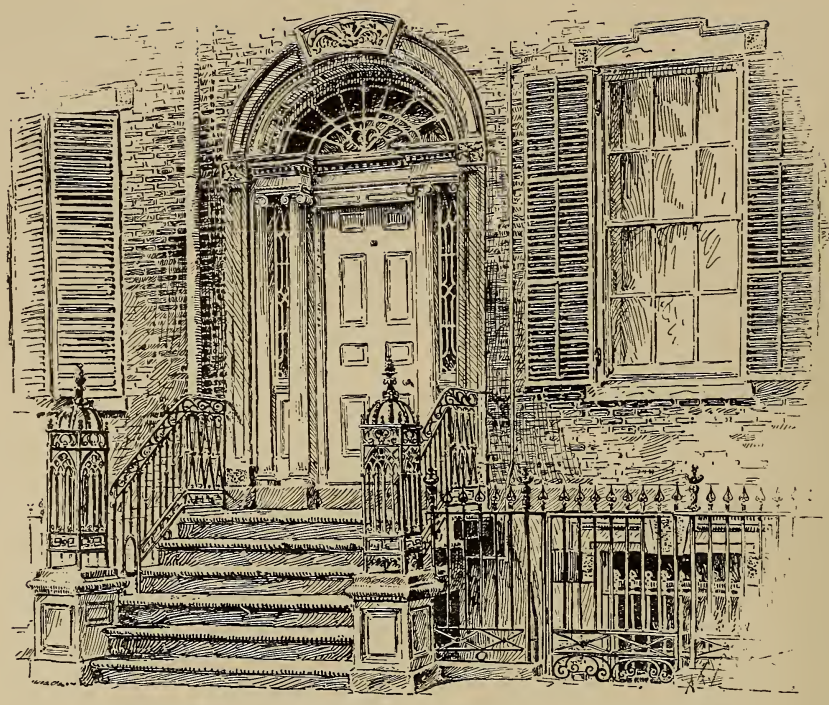
Among Ericsson's papers were found, after his death, a series of autograph pencil drawings, showing these concealed features of his monitor system as originally conceived. They represent the ideas of subaquatic attack, first presented in the Destroyer in 1878, after being withheld from the public gaze by their author for half a century. The rude sketches, here presented in fac simile, are thus for the first time made public. In his work entitled "Contributions to the Centennial Exhibition," published in 1876, Captain Ericsson speaks of them as "unfortunately lost."

the first day. The Confederate claim that the encounter between the Merrimac—or Virginia—and the Monitor was indecisive, in fact, a drawn battle, is well founded. Ericsson recognized this, and while all other voices, save those singing Hallelujah, were silenced, he was more disposed to criticise than to commend. He had been thoroughly trained in the science of artillery in his youth ; through life he had made the subject of ordnance a study, and his engineering experience had given him an unusually thorough knowledge of the strength of material. He built his vessel to carry a gun far larger than any in the service of foreigners at that time, and he believed that this gun could be safely fired with a charge much in excess of that allowed by the timidity of the ordnance authorities. In this he spoke as one having authority, and the result proved that he was right. It was against his judgment that the charge for the guns of the Monitor was limited to fifteen pounds of powder. Later experience showed that they were safe with charges more than three times as great. Firing thirty-five pound charges, John Rodgers, in the Weehawken, with his first shot knocked a hole in the armored sides of the Atlanta, *née* Fingal, wounding with flying splinters sixteen men and prostrating forty more insensible. A second shot crushed in the pilot-house, wounded both pilots and one helmsman, and stunned the other helmsman. Within fifteen minutes the Atlanta surrendered, and the same fate would have overtaken the Merrimac had Ericsson's advice been followed.

Besides the Monitors built by others, nine were built for the government by Ericsson and his business associates, Messrs. Bushnell, Griswold and Winslow, costing altogether between five and six millions of dollars. His labors culminated in the Dictator and Puritan, the latter of which had five times the displacement of the original Monitor, or, in all, 11,002,000 pounds. The Puritan was never completed. The Dictator was the work of Ericsson from beginning to end, the only exception being the boilers. These were of a type he was compelled unwillingly to use, and greatly interfered with the efficiency of the vessel. Model, machinery, engines and propeller, steering and ventilating apparatus, gun-carriages and innumerable devices for increasing efficiency and comfort are all his. Review the history of naval construction, its follies and failures ; remember how many minds unite ordinarily to produce the best models of war-ships, and how difficult it is to successfully translate into wood and iron the ideas recorded at the drawing-board—and then share with John Ericsson in the pride with which, in 1863, he wrote to the Navy Department that the Dictator was afloat with a displacement amounting altogether to 10,000,000 pounds, some fraction of an inch less than he had calculated !

To understand what this means, recall the fact that an engineer officer of the United States navy during the Civil War, following out the Monitor plan, built twenty light-draught vessels at a cost to the public treasury of many millions, and not one of them was ever worth a dollar. Miscalculation had been made in their displacement, and they could not be kept afloat without changes too costly to be made. It is a curious fact that this stupendous blunder excited less comment in naval circles than the alleged deficiencies of Ericsson's Monitors. One of these vessels was fitted up after a fashion, and put into commission. The officer referred to was ordered to duty on board her. The next day he was found at work with a cold chisel, cutting his name out from a plate set into the vessel for the purpose of glorifying his constructive skill by announcing him as her designer.

A British naval captain—Cowper Coles—disputed with Ericsson the honor of originating turret vessels, and undertook to show how superior his own ideas were. He built a vessel on his plan, with the approval of the successors in Somerset House of those officials, who solemnly declared that with Ericsson's propeller no vessel could be steered. This expensive war-ship, the Captain, with its crew of five hundred



EXTERIOR VIEW OF ERICSSON'S HOUSE, 36 BEACH STREET, NEW YORK.

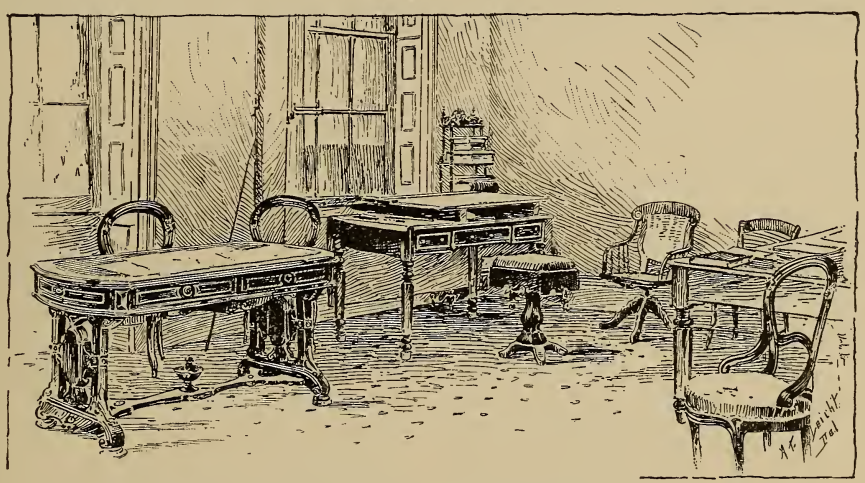
men, had scarcely left the British waters on her first voyage when she turned over in the Bay of Biscay, off Cape Finisterre, in an ordinary squall, and carried to the bottom Captain Coles and nearly every soul on board. A little boat flag, hanging like a signal of distress over a tomb in a parish church in England, is the sole relic of the unfortunate author of this attempt to improve upon the design of the Monitor. It is well to remember not only what Ericsson did, but what he escaped, by his thorough mastery of any subject with which he presumed to deal.

Consider the chances of blundering in a vessel of wholly novel design, built as the Monitor was! Beyond drawings showing the general plan of the vessel, nothing had been done when the contract for her was secured, though she existed fully developed in the brain of her author. In one hundred days everything was completed—working plans drawn, calculations made, contracts executed, the work upon the different parts distributed, and the contractors watched through every stage of progress to see that there was neither error nor delay. Ericsson's labors during those three months were Herculean. After spending a considerable part of each day at Greenpoint superintending the work, he was to be found all through the evening, and far into the night, engaged at the drawing-board in his office in Franklin street. From that wonderful race of vikings, who have had no superiors in physical development, he had inherited the strength of two ordinary men, and he needed it all. Sinews and nerves must needs be of steel to bear the strain. The least halting, even trifling delay, or confusion of mind from bodily weakness, and the story of that eventful day in Hampton Roads would not have been written.

The war over, Ericsson withdrew from public notice, so far as such a man could, and devoted himself to the study of solar heat. In his way he sought to follow Emerson's advice, to "hitch

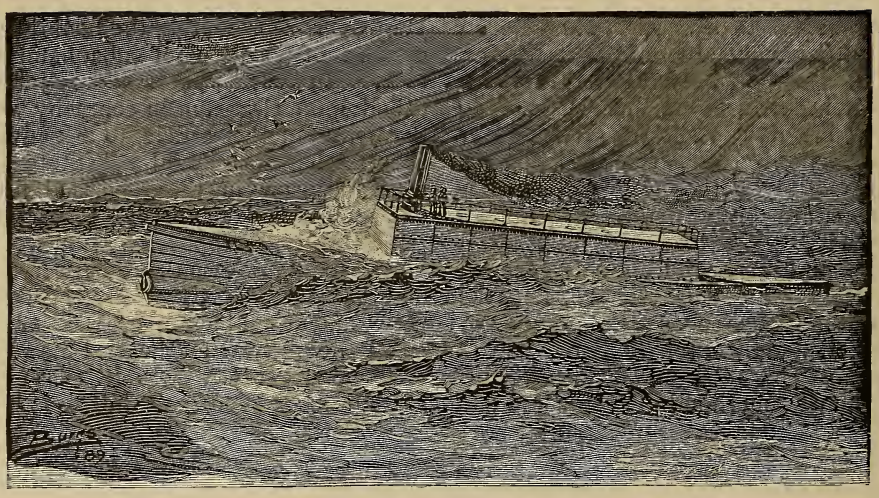
your wagon to a star." He believed that upon man's ability to train the sun to harness depended the future of industrial development, forecasting the inevitable day when the last of our coal-bins will be emptied, and the stores of fuel gathered for us by provident nature through so many centuries expended. He had fitted up for a home and workshop an old-fashioned house at 36 Beach street, opposite the land now occupied as a freight depot, then forming St. John's Park, one of the most charming in New York city. As the neighborhood grew less and less attractive he thought of moving, and one of the reasons he gave for not doing so was the very ungallant one that the ladies had ceased to call upon him there. He was absorbed in his work, and was ordinarily as unapproachable as an Oriental despot. For the first time in his life he found himself in a position to labor for the enjoyment of producing, without reference to a pecuniary return, and this was a passion with him, his sole recreation being a change from one form of occupation to another.

At the solicitation of the chief of the Naval Bureau of Ordnance, Commodore Jeffers, he turned aside for a time from his chosen work to experiment with the Destroyer, representing the final development of his ideas of subaquatic attack. In 1878 Commodore Jeffers called upon Ericsson, in company with the writer of this article, to ask advice as to what he should substitute for torpedoes, for in these he had little faith. Under the assurance that a vessel of the type proposed by him would be accepted, Ericsson put his services and his purse at the disposal of the Government, and again he was left to "pay the piper," for he and his associate in this enterprise—Mr. Cornelius H. Delamater—were saddled with a white elephant in the shape of a war-vessel.



VIEW OF THE ROOM IN WHICH ERICSSON WORKED FOR MORE THAN TWENTY YEARS.

His native land and his adopted country could always command Ericsson's services, whether they were paid for or not. With others he dealt differently. In 1869 the Spanish government appropriated a sum of money to provide vessels to prevent blockade running by the Cuban insurgents. They came to the United States for proposals. One shipbuilding firm proposed to furnish one vessel for the amount appropriated, another two. Neither plan was satisfactory. "Why do you not consult Ericsson?" someone suggested. It was done. "Call to-morrow," he said, "and I will have some-



ERICSSON'S TORPEDO-BOAT DESTROYER.

thing to show you." The plan he presented was at once approved, and specifications more in detail were asked for. These were refused, but he agreed to have thirty gunboats ready for the Spaniards in six months, and within four months from the signing of the contract, and three months and a half from the time of laying the first keel, the last vessel of the fleet was launched and fifteen of them had engines and boilers on board. Into these gunboats various novelties were introduced, and they admirably answered the purpose of patrolling the Cuban waters as a sort of naval police. Each carried a 100-pound improved Parrott rifle, and drew but five feet of water. The decoration of Isabel la Católica was bestowed upon Ericsson by the Spanish government in token of its appreciation of his success.

Of all the men most prominently connected with the events of the American Civil War, Ericsson is the one whose history is least known, and whose personal characteristics are least understood. His absorbing occupation with government work during the conflict compelled him to habits of seclusion, and when the struggle was over he found no time to be lionized, a pastime for which he had no inclination. His work was important, and life was too short for it, as he was already a sexagenarian. In guarding himself against visits of mere curiosity he was obliged to make rules admitting of no discrimination. As his few intimate friends passed away one by one, he formed no new associations. And finally the death of his intimate friend and associate of half a century, Mr. Delamater, gave him a mental shock that aggravated existing disease and resulted in his own death on March 8, 1889.

If he was never willing to pose for the admiration of visitors, Ericsson was always ready to receive those who had specific business with him, and the walls that inclosed him were never so impenetrable that the cry of distress could not reach him. It was the rule of his house that no one who applied for food should be turned away empty, and his solicitude as to the exhaustion of the coal supply of the universe never went so far as to lead him to refuse to fill the empty coal bins of the distressed widows of his neighborhood. To the poor and friendless, or to the injured workmen who came under his observation, he was always the kind friend and adviser—the generous almoner—and he had a pension roll as long as that of a grand duke. The reputation he enjoyed in his neighborhood is shown by the message that came to him from the nearest

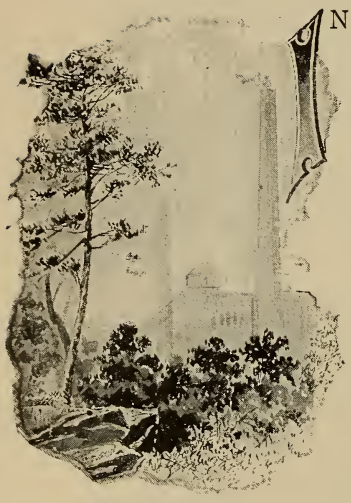
engine house during the draft riots of 1864, that if "the old man" had "any use for the boys," they were at his service. The tears that filled his eyes and choked his voice when he was told the story of the starving Norrlanders of Sweden and opened wide his purse for their relief, testified at once to his liberality, his love of country and his tenderness of heart. Peter Cooper found in Ericsson a congenial spirit, and was warmly welcomed when he called. Ole Bull, a friend of his early years, was received with a hearty Norse hug. In the "Memoirs" of her husband Mrs. Bull tells us of the help extended to him by his friend in a matter that concerned his professional pride. "No friendly service," she says, "ever touched Ole Bull more deeply than the generous helpfulness of John Ericsson, whom he admired and loved." Of her husband, Ericsson wrote: "So warm a heart, and so generous a disposition as his I have never known." "These words," adds Mrs. Bull, in quoting them, "it may be truthfully said, expressed the sentiment and the judgment of the violinist concerning the great engineer and inventor."

Limitations of space have compelled me, in these brief articles, to pass over much of Ericsson's important work, and to confine myself, in some cases, to assertion where I should have been glad to give proof. But the opportunity for this will come when the history of his life is told in full. As I study the letters and manuscripts left by him, I follow with increasing interest and admiration the story they tell of the strength of his intellect, the generosity of his nature, and the lofty purposes which were the impelling forces of his life. Even his weakness were those of a strong man; of a luxuriant nature, wherein wheat and tares grew together abundantly, awaiting the harvest.

What is to follow this age of steam and iron, who can tell? In the future, whatever it may be, for which it is opening the way, men will remember John Ericsson, as one of those whose absolute fidelity to the responsibility imposed upon them by great abilities and grand opportunities, has made possible a new advance in the line of human progress.

# LUBRICANTS FROM A MAKER'S STANDPOINT.

*By Chas. M. Everest.*



IN a paper presented at Chicago before the International Engineering Congress, the author undertook to present a few points about lubricants, and opinions and practices in the use of them, especially noticeable from the standpoint of a manufacturer of lubricants. It is perhaps not too much to claim that, in knowledge of practical lubrication, the manufacturer of lubricants is in advance of the common practice, and that his chief difficulty is to induce the power user to abandon one idea or method for a newer and better one. The author's paper was subsequently published, together with a number of others, in book form by Messrs. John Wiley & Sons, making up the Proceedings of the Division of Marine and Naval Engineering and Naval Architecture, and from this what follows has been substantially reproduced.

The total disuse of tallow as a lubricant for valves and cylinders was due to the ceaseless and determined efforts of the sellers of heavy mineral oils, and few can realize, when contrasting the value of the two lubricants, what tremendous effort this change represents. It would seem now that to induce the user of tallow to leave it for something better would have been an easy matter, but the change came about only through the oil manufacturer—not the steam user, and is a good illustration of the advance in lubrication constantly effected by him.

In asserting the claims of lubrication as a subject of importance, we might resort to an analogy much quoted by writers on "Animal Mechanics," and especially by some of our eminent physiologists. We refer to the comparison made between man and the steam engine. Probably the similarity never has been so comprehensive and pertinent in its bearings as now, when the science of physiology furnishes us with such remarkable facts and generalizations, where previously existed misconception and ignorance.

It will probably be admitted that a conscious or unconscious study of nature has led the engineer to the only simple solution of many intricate mechanical problems. The anatomical structure of the human body involves a wonderful system of joints, the parts of each of which are easily comparable to the bearings and journals of ordinary machinery. The perfect joints in the human frame should exert an irresistible attraction on the practical engineer, if he is desirous of examining the conditions of the only perfect machine. Here we find a journal and bearing both of which are lined with a uniformly smooth layer of cartilage, answering in a measure to the metallic linings adopted by engineers, the chief features of which are two opposing surfaces, with hard, smooth faces, provided with a thorough system for securing economical and uniform lubrication.

The necessity for lubrication, even where the other conditions are perfect, is thus vividly exemplified, and its importance is only more fully confirmed when we consider the evils consequent on the absence of the synovial fluid through accident or disease. If the

effects of insufficient lubrication are so speedily made apparent in a perfect machine, the gravity of the consequences where a necessarily imperfect machine is carelessly or unsuitably lubricated should be promptly recognized.

The early forms of machinery which mankind devised for its needs necessarily wasted a great part of their power through friction, which could not be avoided, no matter what lubricants were used, and the comparative relation of lubricants to the machine assumed the relation which still holds more or less in the public mind, to the detriment of a more rapid advance in the right lubrication of modern machinery. The slow-moving, ponderous machines that were in general use only a comparatively few years ago afforded little opportunity for ascertaining losses of power and gave very few advantages for right lubrication. Almost any sort of grease, whether animal or vegetable, was thought to be good enough, and in a great many instances was good enough under existing conditions.

It has not been very many years since one oil was deemed sufficient throughout a mill or on shipboard, and whether the oil was to be used for the valves of an engine, or on ordinary bearings, or burned in a hand lamp, the same oil must fit each condition. Naturally under such circumstances sperm-oil was the standard, and was not only generally used, but extremely difficult to displace, even in spite of the gradual extermination of the sperm-whale and the rapidly increasing cost of the oil. The wide range of service which sperm-oil covers, and its almost universal use for a long time as a lubricant, have left a disposition to demand another single oil to do, if not all that sperm-oil did, at least to cover as wide a range of conditions as can possibly be contained in a single lubricant; and there is perhaps no greater difficulty than this with which the oil manufacturer, seeking for ideal results, has to contend, even when the advantages of a number of lubricants are clearly manifest. Dr. Thurston places special emphasis on this point. He declares that "the art of economical employment of lubricants consists mainly in the determination of their adaption to specific purposes, and in the application to each machine—or each part of a machine on which pressure of lubricated surfaces of widely differing amount is found—of precisely that quality of unguent which is best adapted to that particular place, and, above all, applying it in the best possible way."

It is of course impossible to have an ideal lubricant for every journal, for this would mean a special oil for every bearing; but if each set of bearings under reasonably similar conditions had fitted to it the most suitable oil, there would be a great gain in friction reducing results, without an undue multiplication of lubricants.

Lubricants may properly be divided into three general classes. One consists of the solid lubricants, such as graphite, soap-stone, etc., and the so-called anti-friction bearings of various composition. While these have their uses, it can scarcely be claimed that they are of as practical service without the assistance of fluid lubricants as with them. Still, the power user can gain much by having all bearings so constructed as to aid rather than retard lubrication, and often the rubbing surfaces can be greatly improved by the addition of these materials in moderation.

A second class of lubricants is the semi-solid greases, which retain their firmness at ordinary temperatures; they have a narrow range of real service, though they are mistakenly used in practice for a wide range of service, resulting in a wasteful consumption of power. The mistake arises through the idea that greases are economical because they consume slowly, but when it is remembered that fluid lubricants can be consumed as slowly when properly applied, and that greases must be reduced to fluids by the resultant heat of friction, their objectionable qualities will be recognized.

It has been observed in mills largely lubricated with grease that the engine, unless abundant in power, could start

only with difficulty when resuming work, and that the load did not lighten until after friction had produced enough heat on the bearings to melt the grease. That use of solidified oils puts a drag on power was recently illustrated in a marked manner in a case which came under the writer's notice. A flour mill at Rochester, N. Y., operated two sets of flouring mill machinery with separate water-wheels. In the hope of economy in cost of lubricants a change was made from oil to grease. One half the mill was first equipped, when a noticeable falling off in speed was observed. It was not at the time attributed to the lubricants, but sought for in other directions. Later the second half of the mill was equipped with grease, when the same diminution of speed was noticed. Cause and effect were then discoverable, and a return was made to fluid lubricants, resulting immediately in the former standard of speed. The loss in this mill from diminished output owing to reduced speed would have been considerable and illustrates how close is the relation of lubrication to profit and loss. It is somewhat interesting that there was no noticeable increase of heat on the bearings with grease over oil, though it must have been sufficient to melt the grease, but the increased drag was self-evident.

There are some cases where power has to be sacrificed to other advantages. For instance, grease is used to lubricate motors on electric cars, because of the difficulty of applying oil, and because oil flies off and saturates the armature, a disadvantage which a good deal of power can be sacrificed to overcome. The right appliances, however, for feeding fluid lubricants in cases of this character will yet be discovered, for the loss of power from the grease is not disputed. Greases are also somewhat used to lubricate railway car axles ; but this is due rather to the imperfect methods of applying lubricants —so wasteful of oil—than any advantage that grease intrinsically possesses, for the friction losses must be as great here as in a mill. Solidified lubricants have had a great attraction at various times for power users, and many mill-owners have equipped their plants at considerable cost, only to abandon the greases and return to oil in the end, because of power wastes. It is a safe rule to use greases only where waste of power is of no consequence, or where the use of fluid lubricant is attended with serious difficulties. It is better still to devise some appliance that will permit the use of oil without disadvantage.

Fluid lubricants constitute the third and principal class, including the animal and vegetable oils as well as the hydrocarbon. The former oils have been treated of so fully and exhaustively by others that there is nothing new to add. The simple fact that they have fallen into general disuse proves at least that something more satisfactory has supplanted them—and that is the hydrocarbon lubricant in its various forms, either alone or in combination with other oils.

The petroleum or hydrocarbon lubricants may properly be divided into two general classes—residual and distillate oils. The residual oils, as the name indicates, are products remaining after the light oils have been evaporated or distilled off, and may differ widely in their characteristics, from the oils slightly reduced by sunning and steaming in the open air to the heaviest grades of cylinder oil. There are almost unlimited variations in the character of residual oils, governed, first, by the grade of crude oil itself, and, secondly, by the manner of distillation and subsequent treatment, which may vary from the most complete fractional distillation used in the manufacture of lubricating oils to that destructive distillation employed in the manufacture of burning oils, giving tar as the residual product, this tar being utilized in the manufacture of paraffine oils and paraffine wax, leaving coke as a final residue.

These heavy residual oils, either singly or in combination, form the basis of the petroleum cylinder lubricants, and if properly manipulated in the

process of manufacture are more useful unfiltered than when made translucent by filtration, because in cylinder lubrication, where the highest steam-pressures are used, an oil is thinned by the high temperature to such an extent that any considerable decrease in body (which always results from filtration of oils) is likely to bring them too near the danger line in the matter of preventing actual metallic contact of the surfaces. For low steam pressures, however, including the low-pressure cylinders of compound engines, oils of heavy body are not so necessary, and the filtered oils answer satisfactorily for this purpose.

The lighter grades of reduced oils give valuable lubricants for ordinary journals. As there are contained in them, in a more or less diluted state, all the greases that are concentrated in the heavier residual oils, and as the degree of this concentration can be governed to a nicety by the manufacturer, he is enabled to meet with them every condition of bearings in which oil of considerable body is required. These oils are usually filtered through bone-charcoal to give them an amber color; and while in the case of oils improperly manufactured this filtration improves the quality somewhat, yet it is of no advantage when the filtration is not resorted to to cover up defects in manufacture. In practice, however, except for lubrication of valves and cylinders, and in general railroad use, the demand is almost wholly for light-colored lubricants. This is largely due to prejudice, for in many cases where light-colored oils are used dark oils could be substituted to better advantage in every particular, although in special cases, as in textile factories, dark oils cannot be used because of their liability to stain. Nevertheless, more buyers of oil are governed by the eye in their purchases than by the actual requirements of their plant.

The distillate oils are of two general classes, the best known being the paraffine oils made from distillation of the tar previously referred to, and afterward decolorized and deodorized by chemical treatment. They vary much in quality, and are very extensively used, principally, however, when mixed with other oils, which may be one or more of the numerous animal or vegetable oils, or mineral oils of a different character. These oils for years have been used to lubricate fast running machinery of cotton and woolen mills, and at one time it was considered (as it is now in Great Britain) that the higher the specific gravity the better the oil for that purpose. There has been, however, a marked modification of these views within the last few years: first, by the conclusion that the lighter gravity paraffine oils gave less resistance; and subsequently by the acceptance of the thinner of the neutral oils, particularly for the lubrication of spindles running in a bath of oil. These neutral oils constitute the second class of distillate oils, and are comparatively new. They are made from an intermediate distillate produced in fractional distillation, and have proved themselves valuable assistants to the electrical engineer and manufacturer of high-speed engines, giving a quality of lubrication that could not be obtained with any other oils; and as their quality can be varied by the manufacturer within considerable limits, they furnish lubricants for all high speeds, from electrical machinery to the step of a ring spindle.

Having these various grades of petroleum lubricants, combinations of them can be made with each other or with any of the organic oils, or with both, by which unusual conditions in any of these classes can be provided for in a manner to give the lowest coefficient of friction. If some one could devise a standard by which mineral oils could be accurately gauged as to lubricating value, outside of actual use, he would be a benefactor to all power users; but so far such efforts have been only partially successful.

When mineral oils first came into use it was commonly believed that they could be accurately compared one with another by relative differences in specific gravity. But practical experience soon made plain that the gravity gave

no considerable indication of quality. To the above test have since been added fire test, flash test, cold test, degree of viscosity, per cent of evaporation, and precipitation test; but there is still some quality which one oil may possess over another which eludes tests of this character, yet which materially affects the quality of the oil as a lubricant. It is somewhat unfortunate, therefore, that there has been a growing disposition to magnify the value of such tests.

It may not be uninteresting to consider these tests somewhat in detail, for while they do not give final or conclusive indications of lubricating value, they are useful to persons familiar with the manufacture of lubricants in determining constituent properties and processes of manufacture. The specific gravity of oil in the United States is usually expressed in degrees Baumé. This was the first standard established for determining quality of lubricating oils; and while it is usually referred to in the specifications of large consumers when asking for quotations on lubricants, it is probably with the expectation that the manufacturer will be limited by such restrictions to the use of certain material, as it has long since been discarded as a conclusive test of the lubricating quality of an oil. However, it is a fact that as the specific gravity of a particular petroleum oil increases the viscosity also increases.

The only object in the consideration of the fire test of a lubricant, as well as its flash test, is the prevention of danger from fire from the use of an oil that will evolve inflammable vapors at a temperature approximating that at which the oil is heated in actual use. It has been generally conceded that the lowest fire test permissible is 300 degrees, which gives a liberal factor of safety under ordinary conditions.

The cold test of an oil, *i. e.*, the temperature at which the oil will congeal, should be well below the temperature at which it is used; otherwise the same conditions would exist as in the use of the semi-solid lubricants, or greases, and the coefficient of friction would be correspondingly increased.

Viscosity, or, to put it the other way, the fluidity of an oil, while a comparatively new test, is a most interesting one. Unfortunately there is no established uniform or standard method for comparing the viscosity of different oils, but it is usually expressed in seconds, and represents the length of time in which a given quantity of oil will flow through a certain orifice at the temperature stated, comparison sometimes being made with water, sometimes with sperm oil, and again with rape seed oil. It seems evident that, within limits, viscosity bears a direct relation to coefficient of friction. Recent experiments of Messrs. Snyder and Cessna, students at Sibley College, show quite clearly this relation. Their tests were made under pressure of sixty-eight pounds per square inch, with pure petroleum lubricants, all products of fractional distillation; and as all the oils used were of sufficient body to be well within the limits of safety, the friction was consequently a fluid friction in every instance, and the curves showing coefficient of friction and viscosity were practically uniform, the oil of the lowest viscosity (most fluid) showing the lowest coefficient of friction. The proposition, therefore, would seem to be a safe one, that the lower the viscosity of an oil (without a too near approach to metallic contact of the rubbing surfaces) the lower will be the coefficient of friction, and this general proposition has been strengthened by results obtained in practical experience. This general proposition would seem to make very simple the adaptation of proper oils to their uses in practical work. But when we consider that each bearing in a mill or factory would probably require an oil of different viscosity from any other bearing in the mill, in order to give its lowest coefficient of friction, and that slight variations in the condition of a particular bearing would change the requirements of that bearing; and, further, that when nearing the "danger point" the question of viscosity alone probably does not govern,—it will be seen that while in lubrication, as in the

practice of medicine, general propositions can safely be made, yet those persons having the most experience, best judgment, and a knowledge of all the characteristics of the material to apply, are best able to prescribe for existing conditions.

With regard to percentage of evaporation, the requirement of the New England Manufacturers' Association is, that an oil shall not lose over 5 per cent. of its volume when heated to 140 degrees Fahrenheit, for twelve hours. The object of this requirement is to prevent losses by evaporation, with the resultant effects.

The precipitation test consists of the admixture of 5 per cent. of the oil to be tested with 95 per cent. of gasoline, this mixture making a very thin and (even where dark oils are being tested) transparent mixture, from which any suspended matter, as free carbon, will be precipitated. It gives, however, no indication of the quality of the oil itself, as the free carbon in improperly manufactured oils can be easily removed.

Though it may not be commonly understood, petroleum is a delicate and sensitive material to manipulate if its original qualities are to be retained in an unchanged condition. Consequently variations in methods of manufacture, whether by design or lack of extreme care, make corresponding changes in the product, which ordinary methods of testing will not discover, but which under exacting conditions will produce marked differences of result. A striking example occurred to the writer in a case some time ago where one of the heaviest residual oils were supplied to a user whose conditions were extremely exacting. He complained that one lot gave clear evidence of lack of value. A sample was secured and tested, and showed in the laboratory every proper quality, including viscosity. Another shipment was sent, and it proved satisfactory. Later another shipment was complained of, which again perfectly stood all the laboratory tests; but the dissatisfaction seemed to merit the fullest investigation, and certain experiments and tests other than those commonly accepted as conclusive proved that the difficulty was really in the oil, —inherent in its manufacture. It is extremely doubtful whether oil buyers who require certain given standards of laboratory tests are better served than those who do not. Indeed, some of the standards are so faulty that to pass them an oil manufacturer must supply oil he knows to be faulty; and, further than that, the best standards can generally be met in their requirements by products that will give inferior results in actual service.

The indifference with respect to better lubrication in common practice retards the manufacturer of lubricants in transmitting to the oil user new knowledge and methods. This indifference arises from several causes. One is the false standards generally prevalent by which lubricants are measured. If journals get troublesomely hot, the oil is wrong; a little heat more or less is of no consequence, and the difference in power required with one oil over another is not only not ascertained, but seldom thought about. Another difficulty is that conservatism—the ruling trait of mankind—which fights all innovations simply because they contravene present ideas and practices, and against which advance must ever contend. Then there is the skepticism that doubts the value of better lubrication, while admitting theoretical claims; and this is strong enough to prevent practical experiment, because it entails some trouble and expense, or, if experiments are made, hinders their thoroughness or clouds their results.

Every day the real service which manufacturers of lubricants could render to the users of them is prevented by the causes above stated, and to their regret they have to largely subvert their ideas to existing opinions, only here and there finding opportunity to demonstrate better things. The only remedy for this is the education of power users to better standards in lubrication—especially that of power consumption, and in this direction the manufacturer of lubricants is doing an earnest and hopeful work.

For our own information, when the question of the value of different lubricants in actual service was under consideration, and for the benefit of patrons, we have measured power in many cases in regular work, and have been surprised ourselves at the loss which unsuitable lubricants have caused, and this too without there having been any trouble from undue friction, or any of the signs by which power users generally judge that friction is excessive. Our experience has been that the statement of Dr. Thurston, in his treatise "Friction and Lost Work,"* that one-half the power of an average mill is consumed in friction, and that 50 per cent. of this loss can be saved by right lubricants, is quite within the limits of practice.

At a large textile mill operated by water-power a full headgate would not keep the mill up to full speed, and as the water supply was insufficient it was impossible to run full ten hours a day. By simply adapting the lubricants to the needs of the work a three-quarters head gave full speed, and water enough was saved to run full time. That oil alone could effect this change would doubtless have been vigorously disputed prior to actual demonstration. The superintendent of another large textile plant, writing us with regard to results from change of lubricants alone, stated that the power in their largest mill had been reduced from 1130 to 1000 horse-power, in another mill from 275 to 220 horse-power, and in another from 455 to 400.

In spindle lubrication the oils generally accepted as satisfactory show marked frictional differences. This is the more surprising because this class of oils has been narrowed to close limits by a gradual process of selection. However, among a number of spindle oils, all of which are considered good, and where the price per gallon varies but a trifle, one oil will require twelve or fifteen per cent. more power than another. Cotton spinners, as a rule, are careful oil buyers ; perhaps no other operators of machinery get better value for their outlay in lubricants, and yet one secures from lubrication much better results than another. The recognition of this fact has led many cotton spinners to depend upon power measurements, rather than oil standards, in determining the value of lubricants. Shafting when poorly lubricated is a large consumer of power. In making a power test in a large worsted mill the shafting was run without load, and it was found that by a change in lubricants and their application 31 per cent. of the power required to drive engine and shafting was saved.

In a test on an English railway, with trains of generally uniform load, conducted on twelve locomotives through one year, it was shown that a definite fuel saving resulted from the proper use of suitable lubricants in place of those not fitted to the work. The coal saving in this case averaged over six pounds per locomotive per mile. The test was confined to valve lubrication only, and in place of a limpid petroleum lubricant, freely fed, a heavy mineral oil was used sparingly. It has been claimed that this practical experiment indicated nothing as to the relative friction-reducing qualities of the oils used because of the "variables" in service, for which allowance has to be made ; but the locomotive superintendent of the railway in question states that, taking one full year with another in the same service, they would be practically uniform, and neither oil would have any advantage.

Some years ago, at a railway master-mechanics' convention, when tallow was still used to some extent as a locomotive valve lubricant, one master-mechanic publicly made the statement that the substitution of mineral valve oil in place of tallow permitted the addition on his road of another freight car to each train,—a gain of power through lubrication of a striking character. In further confirmation of the gain of power from right lubrication of valves and cylinders, we recently found in a test on an 18×42 Corliss engine that 6 horse-power was saved from friction through a change in the valve oil used.

* Published by John Wiley & Sons, New York.

An instructive example of power saving through the continued use of suitable lubricants comes to the writer from England, where, after ten months' use of such lubricants, during which time no change was made in engine, machinery, or load, power measurements showed a saving of 10 per cent. As the power measurements were carefully made, it is plain that the condition of the journals steadily improved by the use of lubricants properly suited to the work, and friction diminished in consequence.

Besides tests of this character, a large number of which we could mention if time permitted, many other cases could be given where the gains of better lubrication have come to the writer's attention in a more general way without measurements of power, such as gain in speed, better service from machinery, better character of work done, etc. In steamship service, for instance, quality of lubrication is known to affect speed. This is so fully recognized by steamship builders, that in tests of certain naval vessels, where extra speed developed would mean large money premiums, oilers were stationed in every possible place, with oil-cans and syringes filled with oil, to squirt at and upon every bearing, to insure full lubrication. That abundance of oil is not, after all, the real essential, is evidenced by the fact that the naval cruiser Detroit, in her famous run, was so complete in her automatic oiling appliances that hand oiling was at no time necessary, and in spite of her great speed her oil consumption was normal.

It is quite safe to say that the general methods of applying lubricants, with a few exceptions, are wasteful, inefficient, and unsatisfactory. One of the greatest advances in the science of lubrication has come along the line of applying lubricants in the right way; for in many instances right lubrication is wholly defeated because of wrong appliances. The most efficient oil cannot be used because of inability to apply it properly, and a lubricant really unsuitable must be used in consequence of the oiling methods. From a journal with a hole in the box to squirt oil through at intervals, to a self-oiling dynamo journal of recent pattern, is a long step; but this sort of advance, with gradations suited to varied conditions, must be made before lubrication can win its best achievements. The builders of high-speed engines have been forced to give much thought to the right application of lubricants in order to save friction troubles that result if the lubricants are not applied properly, and in this they have been followed to a greater or less extent by manufacturers of electrical machinery; but unfortunately many machinery builders have relegated lubrication to a place of secondary importance, which has its effect on the mill operator. The problem of the proper lubrication of valves and cylinders was solved with the invention of the hydrostatic cup, that applied the oil at regular intervals and just as wanted. Methods which insure a continuous application of the lubricant in the quantity required must be extended to all bearings before ideal lubrication can be secured. In the ring spindle the bearing revolves in a bath of oil; there is full lubrication and no waste. In the self-oiling dynamo the oil continuously coats the journal, flows back to its reservoir, and returns again to its work, without waste or loss. But the ordinary mill or machinery journal gets its lubricant in a hit-or-miss style, generally far too thick or viscous to do good service, but thick, because if not it will run to waste. With no better lubricants than in common use a large proportion of the power and oil wasted could be saved by better oiling appliances. To the large amount of waste which the present oiling methods cause is due the idea that much oil is necessary to secure good lubrication. Recently in an electrical plant, where three compound engines were in use, with three generators, consumption was cut down to eight gallons of cylinder oil and twelve gallons of engine and dynamo oil for a run of thirty days of twenty-four hours each, where before the consumption had been about six times greater.

Since true economy in lubrication involves selection from a wide range of lubricants, those best suited to the different conditions, and also the proper application of them, ideal results are to be looked for only when there is such co-operation between the machinery user and the lubricant manufacturer that the requirements of the former shall be fully known by the latter. This co-operation will probably arise first between the makers of machinery and of lubricants, for it occasionally happens now that some manufacturer of machinery confers with the maker of lubricants with reference to the best lubricant for some machine difficult to satisfactorily lubricate. A builder of high-speed engines once stated to the writer that ninety per cent. of the troubles at first encountered by users of his engines arose from inadequate lubrication. If before these engines were offered for general use lubricant manufacturers had known the conditions, suitable oils would have been prepared for them, by special manufacture if necessary; but so long as machinery builders show an indifference to the lubrication of their machines in service, the machinery user will hold to his indifference on the subject. Within the past ten years the general character of lubricants has been materially modified, because of the modified requirements of machinery. Too often these modifications have come after much costly experimenting, which could have been prevented by that co-operation between machinery owners and oil manufacturers which must be one of the important factors in future mechanical engineering progress.

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# THE FEATS OF THE MAGNETIC GIRL EXPLAINED.

*By Nelson W. Perry, E. M.*

"SEEING is believing," is an old saw that depends for its truth very largely upon the individual who sees. We most of us know, however, how fallible is the sense of sight; for it is upon this very fallibility that the sleight-of-hand performer depends for his success. He passes a coin from one hand to the other (or appears to do so), before your very eyes and then, after some diversion or other, in some mysterious manner, again shows the coin in the hand which it never had left. So prone is the eye to deceive itself, that when this simple trick is skillfully done, it will involuntarily follow the palpable itinerary of the coin that its possessor knows full well it does not make.

Neither is the sense of hearing to be relied upon, else the ventriloquist's occupation, like that of Othello, would be gone. But who that has seen Heller or Hermann at his best, would not willingly see him again, though he knew that their performances were but tricks for the deception of the senses. Doubtless, the magicians of the East were adepts in this art, but their tricks have lost none of their mystery by the tales of travelers who have witnessed them. If it be true, as Barnum said, that the public likes to be humbugged, it is also true that this same public, after having been humbugged, itself delights in assisting other publics in becoming humbugged. It becomes a ready accomplice, unconsciously it may be, but nevertheless an efficient accomplice to the performer whose tricks it has itself witnessed.

With the class of tricks above referred to we are all more or less familiar, but there is another class which many of us have seen and of which all of us have, doubtless, heard, and which, although depending upon entirely different principles—viz., the fundamental laws of mechanics—are no less effective. I refer to the seemingly marvelous feats of the so-called electric or magnetic girls which appear to controvert the laws of nature and which, when skillfully performed, never fail to inspire wonderment and awe among those upon whom they are performed as well as among those who are but passive spectators.

The first exponent of this new art, if so it may be called, so far as the writer knows, was Miss Lulu Hurst, of Georgia. Some seven or eight years ago, rumors began to spread of the wonderful feats of strength performed by a slight country girl in that Southern State. She was described as pale and thin, about fourteen years of age, weight about 100 pounds, and of an extremely nervous temperament. Her weight and temperament were always emphasized, the first, doubtless, to show the impossibility of her accomplishing her feats by pure physical force, and the last, as hinting at occult powers which alone seemed adequate to the occasion.

So wonderful were her performances described to be, that people made long pilgrimages to see her and to marvel. Not alone were the uneducated mystified, but even those who pass for people of more than ordinary intelligence came away from her seances convinced with the idea that she was possessed of some inexplicable power, unknown to mortals of ordinary mold. Scientific men, while not sharing this belief in her occult or superhuman powers, were no less mystified. They proposed tests to which neither Miss Hurst nor her manager would consent; so they were left the only argument, that her powers were capable of explanation upon rational principles if it was but permitted them to find out what those principles were.

No less an authority than Professor Simon Newcomb, of the Smithsonian Institution, thought her feats worthy of investigation and he, with other well-known scientists, made the pilgrimage to the little Georgia town where this new star was scintillating in all her brilliancy. He found her as described—young, slight and of nervous temperament, and her whole make-up apparently of such a character as to preclude, at first glance, the possibility of her performing her feats by means of her own, unaided, physical strength. He noticed, however, the play of the muscles in her arms and legs during the exhibition of her powers and discovered, as he thought and proclaimed, an abnormal development of the muscles. His explanation, as widely published at the time, was in accordance with this assumed discovery.

The enterprising dime museum manager saw in her a bonanza, and it was not long before she made the tour of the principal cities, and her fame was spread broadcast. Many imitators who had discovered the secret of her art, sprang up, and the Lulu Hurst's of the dime museum arena became plentiful. Some of these, indeed, far surpassed their prototype in skill and, while some assumed her name, others traveled upon their own reputations, made by performing all the tricks of Miss Hurst, together with others which were equally astonishing and originated with themselves.

It was one of these latter whom the writer first saw in a dime museum in Cincinnati. The performance took place upon a temporary stage, consisting simply of some rough boards loosely laid upon wooden horses at one end of a large hall. The performer was a young girl, pale and slender, and weighing probably not over 100 pounds. She wore short skirts so that the calves of her legs were partially disclosed to view, and her arms were bare. There was certainly nothing abnormal in the muscular development of either her arms or legs; it was, if anything, subnormal, or rather would I say, just such a development as would be ex-

pected in a girl of her slight build. Her manager, mounting the platform, requested that some heavy-weight man from the audience should step to the platform. One of aldermanic proportions, who gave his weight as 240 pounds, stepped up and took a seat in a chair provided for the purpose. Being told to hold the chair down at all hazards, he planted himself firmly within it, with his hands akimbo upon its arms, his feet set solidly upon the floor and his lips tightly compressed. As he sat there he looked the picture of determined immobility, and it appeared as though it would require the strength of a giant to move him. The slightly-built girl, however, advanced to a position behind the chair, where, stooping so as to place the palms of her hands against the legs of the chair just below the seat, soon had both man and chair dancing a lively duo around the stage.

The inability of one man to hold the chair down against her efforts having been fully demonstrated, two more men were invited to assist him. While the first retained his seat the other two

FIG. I. THE CHAIR TRICK.

took up positions on either side of the chair, each with one foot upon the round and the other on the floor, and each with one hand on the arm of the chair while the other was placed upon the chair's back. When all were thoroughly braced for the fray, the young lady placed her hands again in position and essayed to repeat the performance that had just preceded. Surely, thought I, she was attempting an herculean task—she must fail. I watched her muscles intently. They were distended, it is true, but what could the ten or a dozen inches of muscle of her legs avail against the five or six hundred pounds of muscular manhood opposed to it. But the discomfiture of the three men was no less complete, or apparently less easily accomplished than that of the one individual who had first opposed his weight against her strength.

In this first test, the men who took part were all strangers to me, and there was naturally a lurking suspicion in my mind that they might all, or some of them, be confederates of the young woman, but this was entirely dispelled when these men, having left the stage and the invitation having been extended for some muscular man to come up, an acquaintance of mine stepped forward. This gentleman was a fine specimen of physical manhood, standing something over six feet in his stockings, broad shouldered and a trained athlete. He mounted the platform and was given a stout stick, about three feet long, which he was told to grasp, in the middle, in his two hands, extended horizontally, the stick also being held horizontally. He was also told to hold it as rigidly as possible. The young girl then, standing facing him, placed one open hand on either end of the stick so that the ends came in the middle of her palms. The man was to hold the stick still if he could; the girl was to move it and him too if her powers were equal to it. The contest surely seemed an unequal one. She began by giving a slight gyratory motion to the stick, which was easily accomplished and accounted for by the leverage she had. This continued for a moment or two when, quick as a flash, the stick was given such a powerful jerk as to almost throw the big man off his feet. This was followed by another and another, first throwing him one way and then another, until he appeared a perfect baby in the hands of this little girl. In fact, it was only due

to a timely cessation of her efforts and a quick recovery on his part that he was saved from being bodily thrown from the platform.

The house was in an uproar, for the man was well known to many of the audience. He, panting and red in the face from his exertion and confusion, descended from the stage to where I stood. In reply to my inquiry as to how it all happened, he said, "I don't know. I was powerless in her hands. She possesses a power which it is absolutely useless to oppose. I am satisfied she could do anything with me that she chose, but I cannot explain it."

She next did the same thing with two men holding the stick, and could probably have done it equally well had there been three or four. The remainder of her performance was not especially worthy of note, but after it was all over a somewhat professional-looking old man asked permission to hold the girl's hand a moment, which having been granted, he announced in all seriousness to those around him that he could plainly feel the tingling sensation of electricity while his hand was in contact with hers.

I went home in a thoughtful mood. Here was the most marvelous exhibition of power on the part of a child that I had ever seen. I knew that it was not electricity or magnetism as claimed. I also knew that it was explainable in some way, but how? I tried to perform the same tricks with others and the mystery was solved. With a little practice I found that I became as expert as she, although my performance was not so effective to those witnessing it as hers was, because I was a man of full stature and strength.

Sometime afterward I met a man who had seen the genuine Lulu Hurst and he told me of her, to him, wonderful powers. Upon my claiming that I could do all that she had done he was incredulous, and insisted upon putting me to the test. I tried the chair and the stick tricks just described and was successful in both. He was amazed, and turning to me said, "How did you do that? You are surely not strong enough to handle me in that manner." He then desired to try his powers on me, to which I assented. I may say here that if one knows how to perform these tricks he can also thwart anyone else who attempts them on him, so I willingly placed myself at his disposal and his failure to throw me around only heightened his respect for my powers.

Some months later, while in Chicago, I saw the announcement of another electric girl who included in her repertoire a new trick, or at least one that I had not yet seen. I went to her performance, and when the audience was invited to represent itself on the stage I embraced the opportunity and went up. Three other men also went up with me and we were given chairs pending further developments. While the manager was dilating to the audience upon the remarkable powers of the girl, I had an opportunity of telling my companions that I knew all the girl's tricks but one, and I promised them that if they would follow my directions implicitly, in case they were called upon to assist in the tricks that I knew, it would be impossible for her to perform them. They did follow my directions for a while and the girl utterly failed for the time, but she and her manager protested so loudly that they would not do as directed that they were finally constrained to obey, and

FIG. 2. TRYING TO HOLD A STICK HORIZONTALLY.

the seance then proceeded successfully. The last trick performed was the one that I had gone especially to see, and I was called upon to assist in it. A stick, about four feet long, and as thick as a broom-stick, was produced, and I and another gentleman were requested to hold it in a vertical position before us while grasping it firmly in both hands. The girl, standing in front of us and facing us, placed the palm of her open hand against the lower portion of the stick, resting it on the side nearest to us and furthest from herself. After rubbing her hand up and down for a few moments, in order "to make better electrical contact" as we were informed, and after enjoining us to hold the stick perfectly vertically, we were told to press down upon it as hard as we could. This we did until the veins seemed to stand out on our foreheads; but, exert ourselves as hard as we could, we, two strong men, were unable to press down hard enough to make the stick slip past the open palm

FIG. 3. RESISTING DOWNWARD THRUST.

of her hand. Had the girl grasped the stick with her two hands, I am sure she could not have withstood my downward pressure alone. I would have borne her, stick and all, to the floor. But there she stood, with but one open hand bearing against the side of the stick, and both of us could not, by our united efforts, force the stick past that wonderful hand. Surely, there seemed something uncanny about this. But it is very simply explained, as will be seen further on.

Without doubt, the most successful follower of Lulu Hurst is Mrs. Anna Abbott, an American woman who, in 1891, took England and the European continent by storm with her wonderful performances. At that time she attracted the attention of the Prince of Wales, and such scientists as Dr. Oliver Lodge and Professors Crookes, Perry and others were attracted to her seances and were mystified. The newspapers spread her fame broadcast, and one of the prominent English electrical journals attempted, editorially, to account for some of her feats by attributing them to electro-magnetism.

Mrs. Abbott performed the several tricks just described together with many others. A friend of mine who saw her in Winnipeg several years ago, when she was first starting out on her career, has described to me since I began writing this article one of her most effective tricks at that time. Holding a stout stick across the palms of her two hands, extended out horizontally before her, with only her two thumbs over the stick, she defied any one to take the stick away from her. The conditions of the test were that no jerking would be allowed, nor should she be lifted from the floor in the attempt to take the stick away. It is needless to say that although several men attempted to take the stick away from her, none succeeded. This certainly seemed very remarkable, for one needs only to think of it to realize how slight a grip even a very strong man can get on a stick when holding it simply by the pressure of the thumbs against the palms of his open hands. I never had seen this trick performed, nor had I tried it before, but bidding my friend place his cane in my hands, just as Mrs. Abbott held it, I asked him to try to take it away. He was totally unable to do so.

But it is of Mrs. Abbott's later tricks that I wish to speak more particularly. She was recently in New York, and during her stay gave a number of private seances which were described somewhat fully in the daily papers. At one

of these, Sandow, the strong man, was present and invited to attempt to lift Mrs. Abbott. While standing on the carpet she was lifted with ease not only by Sandow, but by a number of others who were present. She called for a board, and upon placing it upon the floor, "for better insulation," she said, even the mighty Sandow was unable to lift her when she stood upon it. In order to "make herself heavy" she not only found it necessary to insulate herself from the floor by standing on the board, but also to "complete the circuit" through the other party. This latter she did by placing one hand on his neck and the other on his wrist. When Mrs. Abbott and her *vis a vis* were thus posed, she gave the latter instructions to lift her if he could, but, notwithstanding the fact that she weighs but a little over 100 pounds, even Sandow, who poses as the strongest man in the world, was totally unable to lift her feet from off the board. This performance never fails to excite wonder, and the more so, because she herself is passive.

By some property, inherent in her

FIG. 4. THE LIFTING EXPERIMENT.

self, she renders nugatory all the efforts of the strongest of men. The natural inference is that, by some means, she renders herself heavy; but, as if to show that she not only possesses this power herself, but that by the simple laying on of hands she can confer this power upon others, she calls in a little boy or girl and challenges any one to lift the latter when she has properly completed the circuit. In this latter experiment, the positions are as follows:—The child stands on the board, facing the man who is to do the lifting.

FIG. 5. ANOTHER LIFTING TEST.

The latter may catch the child as he chooses and will, doubtless, place his hands under the armpits. Mrs. Abbott, standing behind, but a little to one side, places one of her hands on the child's back, between the shoulder blades, and the other one she reaches over and places on the lifter's shoulder, neck or forehead. It is almost pathetic to see the utter inability of a strong man to lift a little child, eight or ten years old, when Mrs. Abbott has thus "closed the circuit;" but that it is an absolute fact can be easily demonstrated, as I know from personal experience.

There are also many other tricks in the repertoire of the so-called electric or magnetic girl which might be mentioned, all of which seem, at first sight, to involve either the possession of superhuman strength, or else some occult power. As a matter of fact, however, they involve neither. The strangest part of them is that they are all within the ability of any of my readers to perform. Furthermore, it will be found that the very mechanical laws which these tricks appear to set at defiance are the ones upon which they depend for their success, and the chief

reason why they have remained mysteries to those who have witnessed them is that they have not tried to repeat them themselves upon the first opportunity afforded.

Let us take the first trick mentioned, namely, that of lifting a heavy person in the chair. Tell him to sit down and hold the chair against all your efforts. He will plant his feet firmly on the floor, thus throwing his weight chiefly on his feet instead of on the chair, as he thinks he is doing. If you are in doubt of this, try it yourself and you will realize that it is a fact. To move the person, all that the girl has to do is to get behind and push. In the stooping position which she assumes, she will obtain a considerable purchase by bracing her arms on her knees and will thus have no difficulty in raising the chair slightly. As the sitter assumes a new position, so as to more successfully resist this effort on the part of the girl, she suddenly relaxes her push, directing the chair off to one side or the other. Before the sitter has recovered himself, she has raised the chair again, and he is allowed to throw himself again and so on; the stronger he is, and the more he opposes or strives to oppose her, the worse he is off, and the more successful she will be. The trick is more effective if three men try to hold the chair down, because of their divided effort and the tendency, where more than one is opposing her, for them really to oppose each other, rather than her. She will be perfectly powerless, however, should even a single person sit listlessly in the chair, with no thought of opposition.

Let us now consider experiment No. 2, where a strong man endeavors to oppose her efforts to move him, while holding a stick horizontally in his two hands. She places the palms of her hands on the ends of the stick and by pressing, first gently and then more forcibly, in a given direction on one end of the stick, she compels him, at great mechanical disadvantage, to oppose such pressure. Thus while she is exerting but very little force, he, having the short end of the lever, may be exerting himself nearly to the utmost. When she realizes this, she suddenly gives in to him and even adds her own slight effort to his, and the stronger he is and the heavier, the harder he throws himself. When he has once done this, the girl has him completely at her mercy, for she keeps him off his balance and he exerts himself only to throw himself the more. With two men, or three, holding the stick, the trick is quite as easy or even easier, for there is never exact unity of action in such cases, and the men will frequently oppose each other and thus, at times, materially assist the girl.

Perhaps the most effective of all of the tricks is the one illustrated in Fig. 3. The whole secret in this consists in insisting upon the men holding the stick in a vertical position. When the girl's open hand is first placed against the lower portion of the stick, she moves it two or three times up and down, pulling gradually more and more against it. As this tends to pull the stick away from the vertical she insists that the men keep it straight. Thus cautioned, they will exert more and more effort until, when she feels that the pressure against her hand is sufficient, she instructs them to push down with all their might. They do so and imagine that they are exerting a tremendous vertical thrust, whereas their vertical effort is actually very slight—insufficient even to overcome the friction of the stick against her moist hand. The men are, really, exerting a tremendous effort, but are deceived as to its direction. With their hands tightly grasping the upper end of the stick, they are really trying to force the other end of the stick against the palm of her hand.

In order to show just how far this was true, I weighed myself accurately on the scales and, while still on the platform, essayed the role of the electric girl, and while two powerful men were exerting every muscle to push the stick past my open palm, I had myself weighed again. The increase of weight would, of course, be the measure of their united vertical thrust. In one

case this increase was twenty-five pounds, and in another, twenty-four pounds. This, of course, was insignificant, and since my arm would naturally take the direction of the resultant of the horizontal and vertical efforts of the men, the strain upon me was merely a tensional one in the direction of my arm.

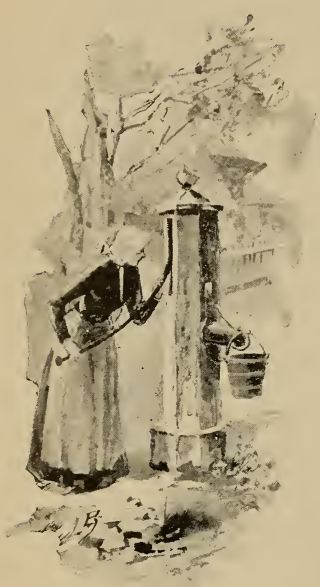
In the lifting experiments in which Mrs. Abbott apparently makes herself so heavy that no one can lift her, she succeeds simply by holding the lifter at such a distance from herself, by means of her extended arm, that he must apply his strength under very great disadvantage. It will require a man of more than average strength to lift, under these conditions, so slight a weight as fifty or sixty pounds and, therefore, a woman weighing 103 pounds, which is said to be Mrs. Abbott's weight at the present time, can safely defy even so strong a man as Sandow.

In the experiment with the child, a slightly different procedure is necessary, for a powerful man would be able to lift the child where he would utterly fail with a person twice its weight. In the case of the child, the hold of the lifter will be much lower than in experiments with an adult, and he must lean over further for the purpose. He is, of course, kept at the proper distance from the child, even though leaning over, by the performer's hand on his shoulder. In this position his lifting effort will not be in a vertical direction as he imagines, but in the arc of a circle whose tangent will be but a few degrees from the horizontal. He is, therefore, unconsciously working at great mechanical disadvantage in endeavoring to force the child's weight nearly horizontally, and all that the performer has to do is to counteract this horizontal push, or rather the resultant of the vertical and horizontal efforts of the lifter, by the gentle pressure of the other hand which, as before described, rests between the shoulder blades of the child upon whom the lifting experiment is being tried. One need only try either of these experiments according to directions to become perfectly convinced of the adequacy of the explanations.

In the experiment where the stick is merely held by the pressure of the thumbs as it rests on the open palms, the very weakness of the performer is her essential element of strength, for her arms will follow every effort made to take it from her and he cannot, for this reason, exert much force against her. If he be in earnest, however, as he usually is when facing an audience, he will exhaust himself fruitlessly in exertions in one direction with one hand while he opposes these efforts by equal exertions in the opposite direction with his other hand. In fact this last trick is exactly the converse of the two first described. In those it was shown that success depended entirely upon the earnestness with which those assisting the performer opposed her motions and that, if they became passive, her efforts would not avail. In this case the performer herself becomes passive, and the efforts of her opponent become, therefore, futile and useless.

# BORE HOLE WELLS FOR TOWN WATER SUPPLY.

*By Henry Davey, M. Inst. C. E.*



A NEW system of bore hole wells for town water supply was proposed by the author a short time ago, and since then has been carried into effect at several places in England. One of the most important examples of executed work in this field, viz., that of the Netherly pumping station of the Widnes waterworks, was described by the author before the British Association for the Advancement of Science at a recent meeting.

The system is shown in Fig. 1 of the illustrations on the following pages. In procuring water for town water supply, it is the usual and necessary practice to provide duplicate pumping engines, and where two engines are made to pump from the same well, the well must be very large, so that it may accommodate two sets of pumps. Such wells are usually from 12 to 14 feet in diameter.

To sink such a well in the ordinary way is a very long and costly undertaking, especially if soft strata are met with, where lining becomes necessary. On the completion of the well, it may be necessary to drive adits to increase the water supply. A simple bore hole is made very cheaply and very expeditiously. Four 30-inch bore holes can be put down in a very small fraction of the time required to sink a 12-foot well. Instead of making a large well, the author puts down four bore holes to accommodate the pumps for duplicate pumping engines—a pair of pumps to each engine. The bore holes being completed, the pumps are lowered into them, and coupled up to the permanent engines. Immediately that is done, the water found in the bore holes can be pumped and supplied to the town. Should it be insufficient, then a small well would be sunk in the dry to the bottom of the bore hole pumps. The water being kept down by the pumps, the bore holes at the level of the pumps would be connected to the centre well, and adits driven to collect more water. Should the bore holes yield sufficient water, it would not be necessary to sink the well. It would be absurd to advocate any particular system of well-sinking as being universally applicable; the advisability of its adoption in any particular case must be a matter of judgment with the engineer planning the work.

The bore holes at the Netherley station, two in number, are sunk in red sandstone rock, and are placed 20 feet apart, each being bored to a diameter of 30 inches for a depth of 200 feet, and to a reduced diameter of 18 inches for further depths of 200 feet and 300 feet respectively, thus making the first hole 400 feet deep, and the second one 500 feet deep. On the completion of the boring, the water stood from 70 to 80 feet from the surface of the ground, when the quantity pumped by the old engine on the same site was 1¼ million gallons per day. The main pumps were then lowered into the bore holes, each pump extending to the bottom of the large part of the hole, 200 feet from the ground level. In that position, the pumps were suspended from a

cast-iron bed plate, supported on a concrete foundation, formed round the top of the holes, a block of oak being inserted between the head of the pump and the bed plate. In this suspended position the pump works without the slightest unsteadiness.

It must be observed that, no temporary pumping plant being required, the main engines were erected while the bore holes were being made, so that, on the completion of erection of the engines and pumps, water could be at once supplied to the town ; but it remained to be proved what was the quantity of water available. The engines were made for the purpose of pumping 2¼ million gallons per day, but it was found that, working up to their full capacity of 2¾ million gallons, the full yield of the bore hole was not reached. On starting the new pumps, it was found that when pumping 2¾ million gallons per day, the water level was lowered to 100 feet from the surface of the ground.

Had the yield of water being insufficient, then whatever water there was might have been sent continuously to the town, while the small well A, shown in Fig. 1, was sunk, and adits driven, say, at a depth of 180 or 200 feet from the surface for the purpose of collecting more water. In chalk this would probably have been necessary, but in sandstone water circulates more freely. In this and in other cases, in sandstone, it has not been necessary to drive adits. Similar bore holes and pumps have been put down in red sandstone at Fleetwood, Kingswinford and other places in England with equal success.

Fig. 5 shows an example of the application of a bore-hole pump to increase the water supply by pumping from a lower level. The well A was originally supplied from the bore hole B, but it yielded only 600,000 gallons per day, when the water level stood 55 feet from the ground level. The author then devised the mechanical motion shown in the illustration, and, by attaching it to the engine, made it work the double-acting pump shown in the bore hole, thus lowering the water

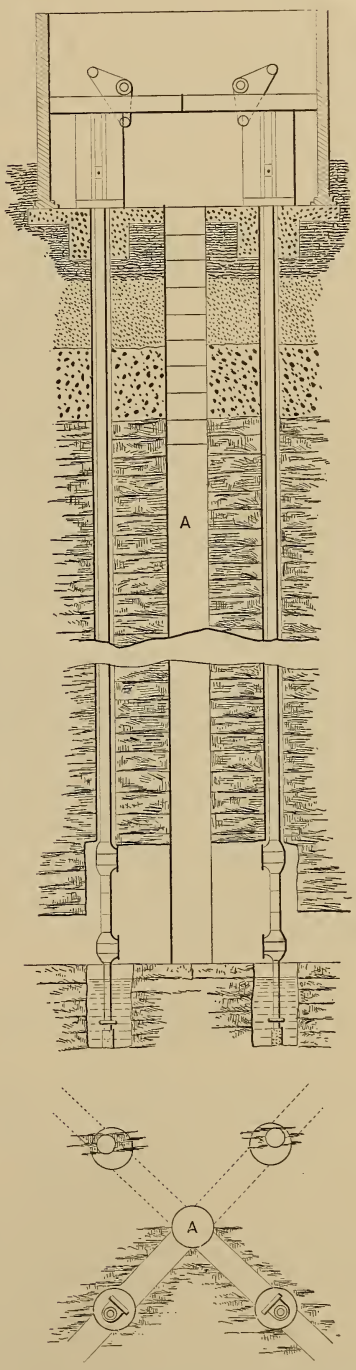



FIG. I. A BORE HOLE WELL SYSTEM.

level in the bore hole 100 feet, increasing the hydraulic gradient of the water supplying the bore hole, and thereby augmenting the supply and raising it from 600,000 gallons to 1,600,000 gallons per day.

The motive power consists of a 230 horse-power compound, surface-condensing engine, employed to pump from the bore hole into a masonry tank by the engine foundations, from which tank the water is forced by the same engine to a reservoir at an elevation of 260 feet. The engine is illustrated in Fig. 2. It is made to work to work expansively. There is a separate expansion valve to each steam cylinder, and there are also cushioning valves on the high-pressure cylinder. In non-rotative engines, in which the cylinder clearances are necessarily larger than in rotative engines, compression is an important element of economy. This steam distribution is effected, as pointed out, without rotative motion or a fly-wheel, by giving the peculiar bell crank form to the levers which convey motion to the well pumps.

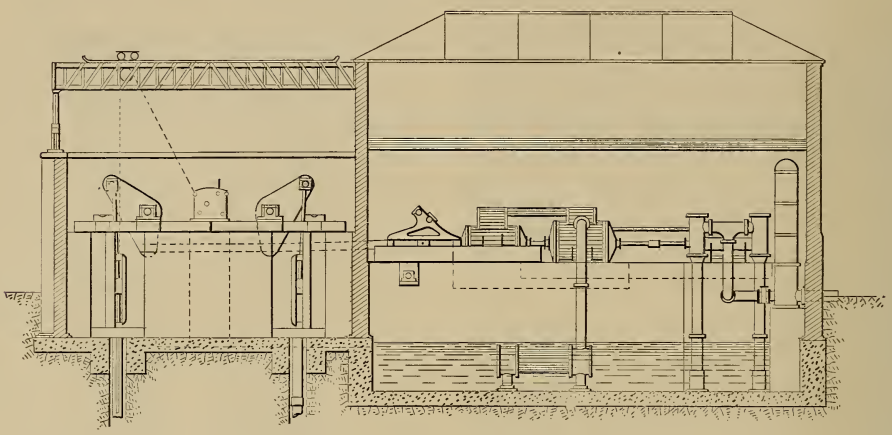
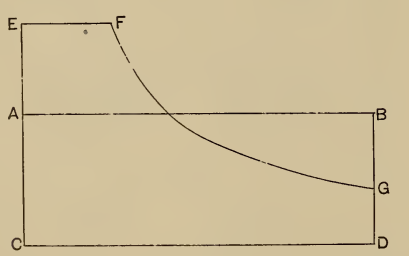
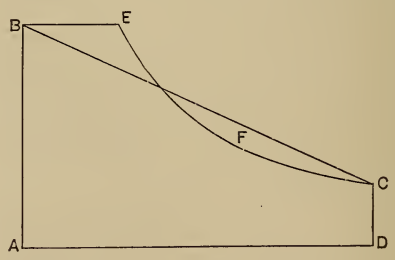


FIG. 2. CROSS SECTION OF ENGINE HOUSE.

In Fig. 3 let the pump resistance be represented by the parallelogram A B C D, and the engine power diagram by the figure C E F G D, and supposing the parts of the engine to have no weight, then means are required by which the piston of the engine may move with varying velocities relative to that of the pump piston.




FIGS. 3 AND 4. PUMP AND ENGINE CARDS.

the force pump by means of a tail rod from the low-pressure cylinder, the bore-hole pumps being worked by means of rocking levers actuated by a connecting rod from the crosshead of the engine. There is no fly-wheel or rotary motion, but a very simple expedient was adopted to enable the engine

Let A, Fig. 6, be the engine, B the

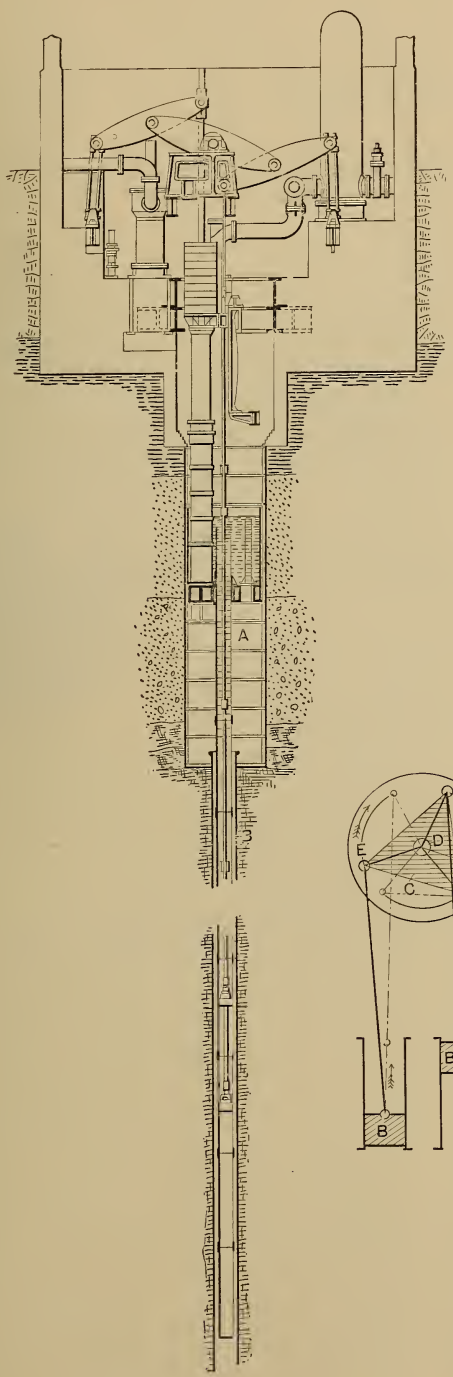



FIG. 5. PUMPING FROM A LOW LEVEL.

pump pistons, and C a triangular frame turning on a fulcrum D. The pump pistons are attached to the frame at the points E, by means of vibrating connecting rods, and the engine piston is connected to the point F by means of a similar rod. While the engine is making its stroke in the direction of the arrow, the pump piston is decreasing in velocity relative to that of the engine piston, the ratio being determined by the relative positions of E and F.

The effect of this mode of coupling the pump piston, or plunger, to the engine pistons is to make the pump resistance diagram so nearly approach the shape of the combined engine diagram that the weight of the moving parts of the engine is, in itself, by its inertia sufficient to equate the two diagrams as illustrated in Fig. 4, in which B A C D is the pump resistance diagram and A B E F C D the combined engine diagrams. In the case of the Widnes engine, the compensating device just described is applied to the bore-hole pumps only. The water raised by the bore-hole pumps is lifted to the reser-

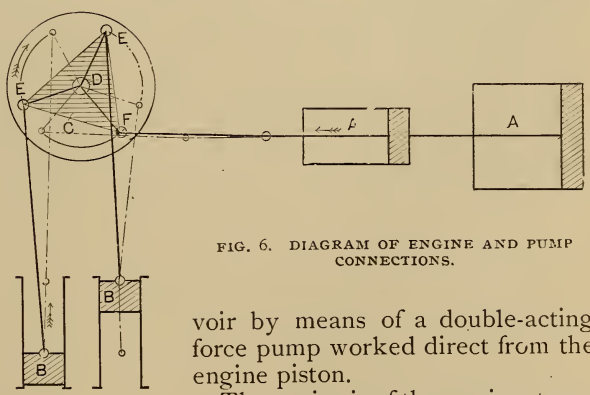



FIG. 6. DIAGRAM OF ENGINE AND PUMP CONNECTIONS.

voir by means of a double-acting force pump worked direct from the engine piston.

The engine is of the receiver type, having separate expansion valves on both high and low pressure cylinders, adjustable by hand while the engine is in motion. The steam cylinders are both steam jacketed completely, bodies and ends, with steam at boiler pressure.

The valve gear consists of a D-slide valve on each cylinder, actuated by means of a rocking shaft, deriving its motion from a water cylinder, worked by

pressure from the pumping main. This arrangement has, among others, the advantage that, should the water main burst, the engine suddenly stops of itself. On the back of each of the D-valves is a pair of Meyer expansion valves, worked by a rocking shaft, which derives its motion from the engine itself. The effect of the combination of the motions of the main and expansion valves is similar to that produced by the author's differential lever gear, but having many mechanical advantages over that gear. The main valves move uniformly and independently of the engine. The expansion valve rests on the back of the main valve, and is moved by the engine. Both travel in the same direction, and the quicker the engine goes, the quicker will the expansion valve cover the port; with no load on the engine, it covers the port at the instant the port begins to open, because the engine motion then responds very promptly to the opening of the port. Between the engine and the surface condenser is placed a feed-water heater, which raises the feed water to a temperature of 110° Fahr. before it passes into the boiler.

The bore-hole pumps are made of lap-welded steel tubes with wrought iron flanges screwed on. A steam winch is provided for drawing the pump rods and for changing the working parts of the pumps.

For indicating the water level in the bore holes, a pipe is put down outside the pumps. At the top of the pipe in the engine room is fixed a sensitive pressure gauge; below the gauge is a branch communicating with a small air pump worked by the engine. The pipe is thus kept filled with air, and the hydrostatic pressure on the outside of the tube is thus shown on the pressure gauge.

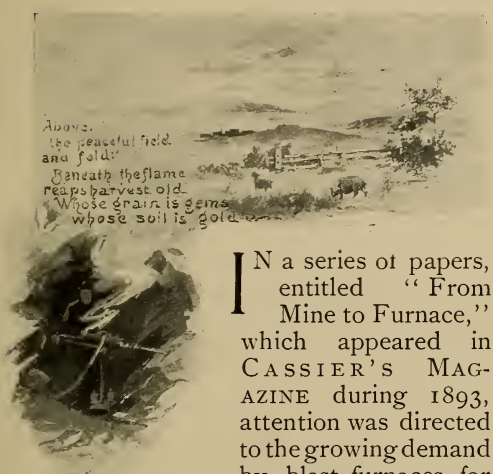
The following summary gives the general particulars and cost of the installation:

| | |
|---|---|
| Steam presure ..... | 70 lbs. per sq. in. |
| Diameters of cylinders... | 32" and 60" |
| Length of stroke ..... | 6' 3" |
| Diameter of force pump. | 18½" |
| Height of lift..... | 260 feet. |
| Length of stroke..... | 6' 3" |
| Diam. of bore hole pumps | 18½" |
| Height of lift..... | 100 feet |
| Length of stroke ..... | 6' 6" |
| No. of strokes per minute | 12½ |
| Depth of bore holes..... | 400 and 500 feet. |
| Diameter of bore holes.. | 30" for 200 feet down and then 18" |
| Tube surface of condenser | 420 sq. ft. |
| " feed heater. | 140 " |
| Water pumped in 24 hrs. | 2,500,000 gallons. |
| Duty of engine, on an evaporation of 10 lbs. water per 1 lb. coal.... | 124,000,000 |
| Lbs. of steam used per I. H. P. per hour..... | 15.6 |
| Lbs. of steam used per P.H.P. per hour..... | 18.0 |
| Indicated horse-power... | 230 |
| Pump horse-power..... | 200 |
| Mechanical efficiency.... | 87 per cent. |
| Cost of engine and pumps | £6000, |
| " " " | per P. H. P. £30 |

# HOW IRON IS MADE.

*By John Birkinbine, Past Pres. Am. Inst. M. E.*

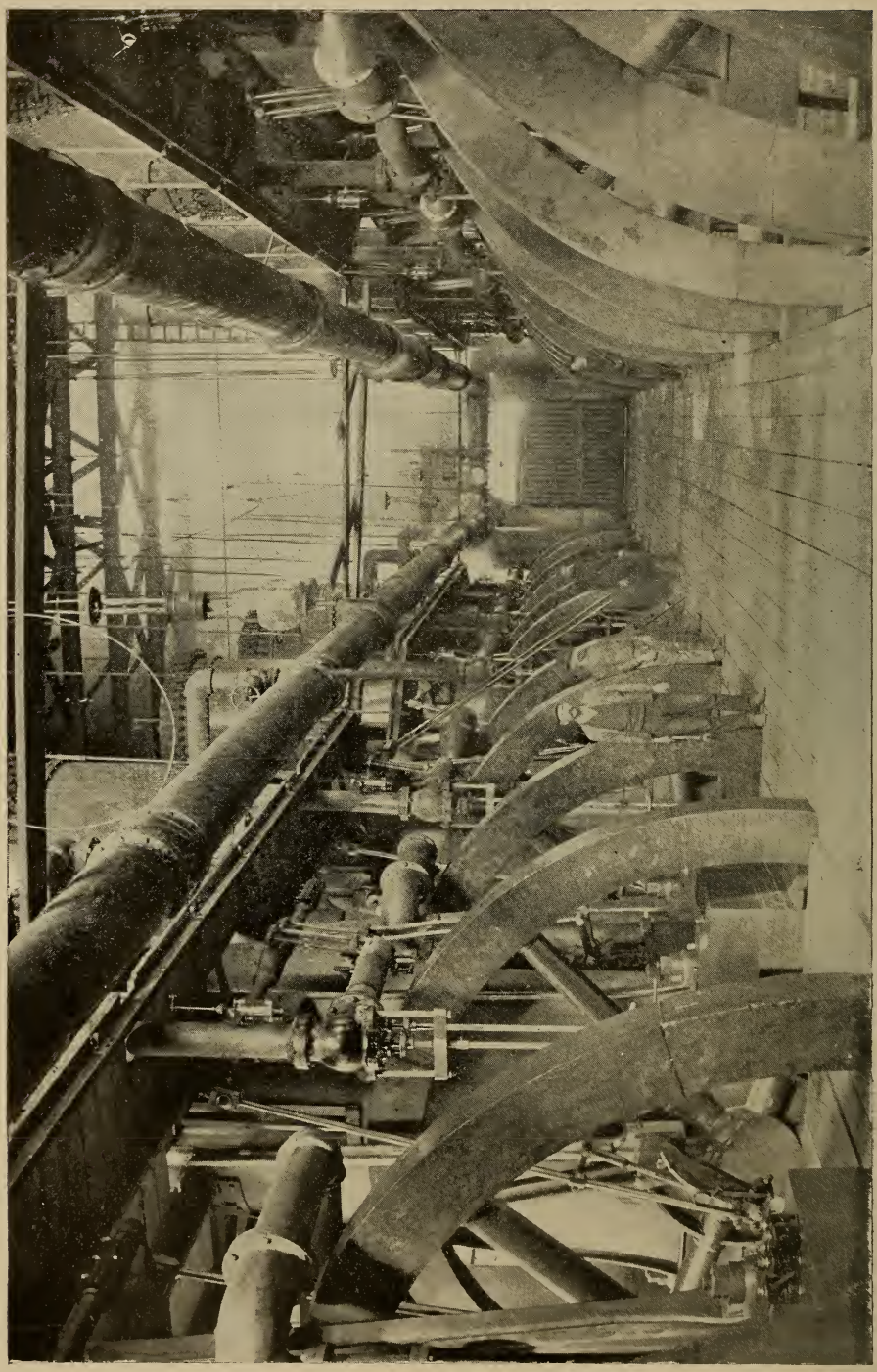
Third Paper.




IN a series of papers, entitled "From Mine to Furnace," which appeared in CASSIER'S MAGAZINE during 1893, attention was directed to the growing demand by blast furnaces for ores carrying high percentages of iron, causing such ores to be transported over great distances which separate the mines producing the ore from the blast furnaces smelting them. This comparatively remote ore is used although near to many of the furnaces in the older iron-producing sections of the country numerous iron ore mines are idle, and will probably continue so until means are discovered of enriching the lean, or of economically utilizing the comparatively inferior, ores which they produce. The inducements to use ores rich in iron increases in much greater ratio than the relative percentages of metal which they contain, for, omitting from present consideration details of chemical composition and physical structure, ores carrying liberal amounts of iron have the following advantages over those containing smaller proportions :—1. To produce a given quantity of iron, less ore, less flux, and less fuel are required, and less cinder results ; therefore, the cost of handling materials per ton of product is reduced and smaller space is required for stock or for cinder dumps. 2. As before stated, the fuel burned in the crucible controls the output of a blast furnace ; therefore, if less fuel is required per ton of product, the raw materials for a greater amount of pig-iron can be under treatment in a given furnace at one time, and a greater output can be secured with the richer ores. The items of interest on cost of construction and of depreciation, the expense of management, skilled help and office force can, therefore, be divided by a larger tonnage. If to these, and other minor reasons, is added a comparison of components other than iron in various ores, and their physical condition, it will be evident why an ore yielding sixty per cent. of iron may command nearly double the price per ton of another ore carrying but fifty per cent. of iron.

The selection of the ores, fuel and flux necessary is no less important than the judicious choice of apparatus and machinery or methods of construction, for a poorly-equipped furnace is as badly handicapped as is one dependent upon inferior raw materials. One of the prime essentials of a good blast furnace is efficient blowing machinery, backed up with a boiler plant of ample power to operate the blast equipment.

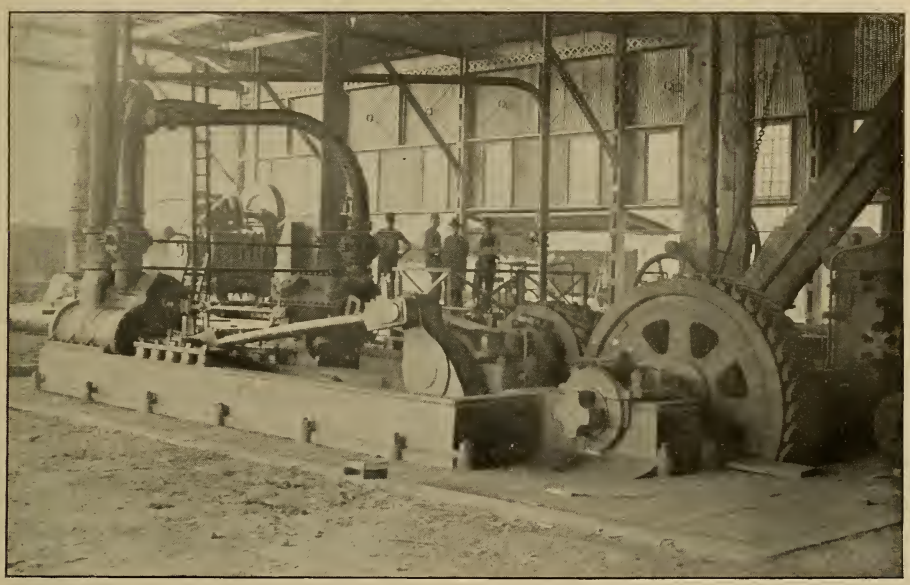
Reference has been made to the probabilities that blowing apparatus used in connection with the production of iron in America did not embrace the crude appliances which were operated by manual, or even animal, power ; but this statement should not be interpreted



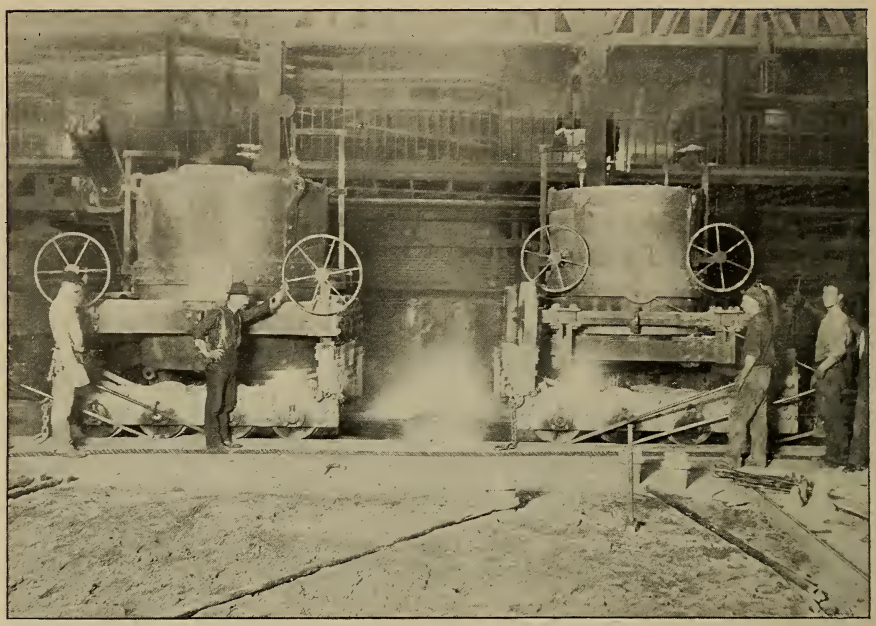
A SET OF BLOWING ENGINES.

as intimating an absence of improvement in the United States of the mechanisms supplying the power to drive into the furnace crucible the air demanded for the combustion of fuel. Until the latter half of the present century the abundance of wood, its cheapness and the ease with which it is brought into shape, caused it to be employed in construction in preference to iron, which was comparatively scarce or expensive, and which was machined with difficulty owing to the imperfect and weak tools then accessible. Consequently, the older blowing machinery was constructed mainly of wood and leather. One of the early forms was restored by the writer for illustration from records supplemented by the testimony of an octogenarian mechanic in an important suit affecting the water right of a blast furnace in the State of New York. This mechanism was in use about 1810, and consisted of a water wheel operating by cams two large bellows made of wood and leather, the return motion being obtained by levers with weighted boxes at the outer end. Some forms of bellows were wooden boxes, hinged at one end, which moved in others slightly larger.

Another form of apparatus consisted of wooden tubs, in which moved pistons packed with leather. The pistons which received motion from a water wheel through crank and rods drew in air on the up stroke and forced it during the down stroke into a third cylinder, in which was a floating piston, weighted to the desired pressure. Some of these blowing tubs were circular, but many of them were square in section, with corners filleted. The writer removed an arrangement similar to that illustrated in 1877 and replaced it by a modern steam blowing engine. The trompe was used principally in connection with forges making wrought-iron directly from the ore. This is an ancient appliance in which a volume of water falling in a vertical box draws air in through apertures in the side, compressing it in a wind box near the bottom. As the improvement in machine tools permitted, iron displaced wood, and horizontal iron blowing cylinders, operated through gearing by water wheels, and later by steam engines, came into



A ROLLING MILL ENGINE.



CASTING AN 80-TON ARMOR PLATE AT THE BETHLEHEM IRON COMPANY'S WORKS.

use, and a few are still employed at some blast furnaces. These iron cylinders were double-acting, with hinged flap valves of leather fitting against grated openings in the heads.

The development of the steam engine naturally suggested connecting the steam and air cylinders, and these have been arranged as horizontal engines with tandem or with parallel cylinders; as vertical engines, with steam cylinder superposed on the air cylinder, or with two air cylinders on either side of the steam cylinder; with the blowing cylinder superposed on the steam cylinder; with the steam cylinder horizontal, and the blast cylinder or cylinders vertical; and with the two cylinders operated from either end of an overhead beam or from side beams. Types of all of these engines can be found operating in connection with American iron works, the valves used in the air cylinders are almost as varied as the forms of engines; hinged flap, grid-iron, gravity discs, spring disc, oscillating valves, either automatic or having a positive motion, applied from the moving parts of the engines, are in use.

As the demands for iron and the size of furnaces increased, the quantity of air required was augmented, and advances in metallurgy made the use of higher pressure necessary. Instead of 500 to 1000 cubic feet of air, delivered under a pressure of a fraction of a pound, individual engines now supply 20,000 cubic feet of air per minute at pressures ranging from 5 to 20 pounds per square inch, and the power of several engines is concentrated on one furnace.

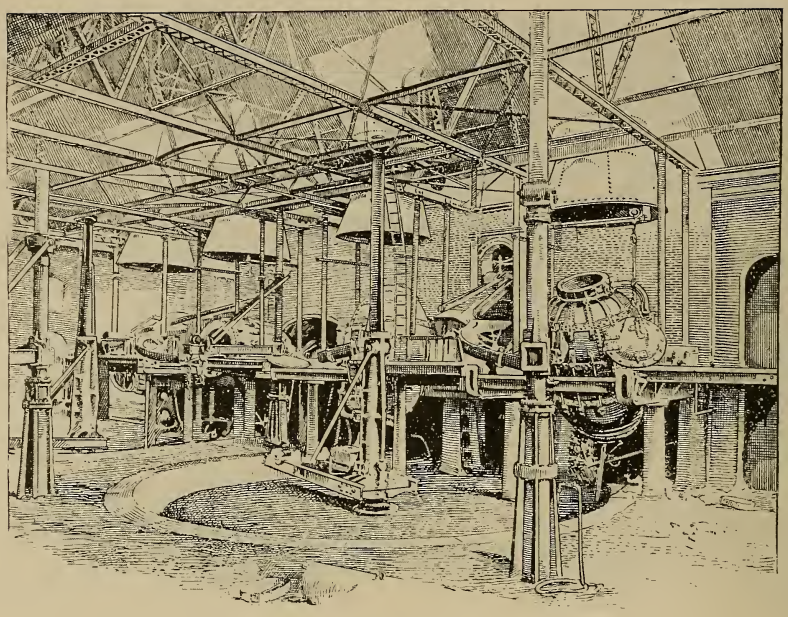
Notwithstanding the study and attention which has been bestowed upon the smelting of iron, and upon the design of machinery used in the process, there have been noticeable cycles when changes evidently won favor largely because of imitation, rather than by research. An unusual yield of iron or low fuel consumption at one blast furnace has often been followed by a change in shape of other furnaces to conform to the proportions of the individual plant whose record attracted attention, and furnace managers have passed through what might be considered, in modern parlance, crazes for high and steep, or low and flat boshes, thick and

thin walls, moderate and excessive cooling, wide and narrow throats, etc. Certain general types of machinery, too, have passed through times of favor or disfavor. In most of the wooden blowing cylinders the pistons moved vertically; with the introduction of iron cylinders and steam engines, the motion was horizontal. Gradually the horizontal type was almost totally displaced by the vertical design, and just now horizontal blowing engines are claimed as superior by some builders. In either form there are advantages and disadvantages in construction or operation which it is not necessary to detail here, but until the duty demanded of the blast furnace shall be different from what it is to-day, the mechanism which will give the best results in continuous operation for a series of years, require the fewest stoppages or the least expense for repairs, will most nearly meet the requirements.

The variety of form and arrangement of hot blast stoves has been as marked as in blowing engines, and even the boilers used about the furnaces have been more or less different in design and setting, in certain districts of the country. In the pipe hot blast stove, the pipe has been circular or elliptical in section, the two legs being cast together with a U top, or joined to a separate casting; small pipes have been placed within larger ones, or pipes have been cast with diaphragms in them. The pipes have been rested on bed pipes, uniting two pipes, or they have joined different bed pipes. In some of the older forms of stove the pipes were placed horizontally, but, as a rule, they stand vertically or are suspended so as to hang vertically in the heat chamber.

In the construction of the regenerative hot blast stove there have been a number of modifications in which the gas has from one to ten or more passes through partitions in fire brick checker work, the air traversing from three to ten passages. Where the number of passes is even, the products of combustion are vented from the bottom of the stove into a chimney; where the number of

BLOWING A HEAT AT NIGHT IN A BESSEMER CONVERTER



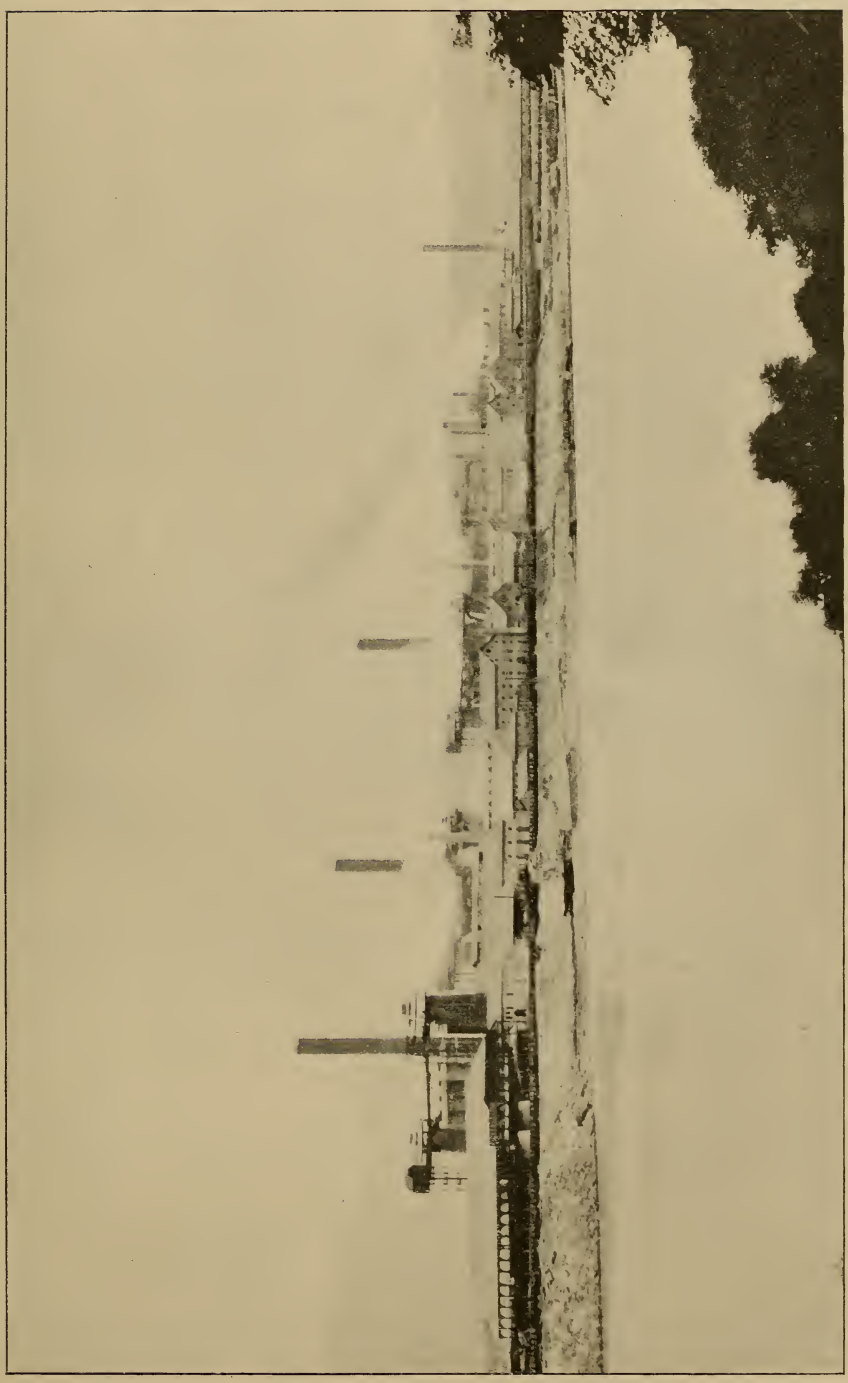
INTERIOR OF A BESSEMER CONVERTER HOUSE.

the passes is uneven, independent chimneys are ordinarily placed on top of the structure. Different designs covered by patents provide for the combustion chamber at the side or in the centre, for peculiar shaped brick or for specific arrangement of the checker work, valves, etc.

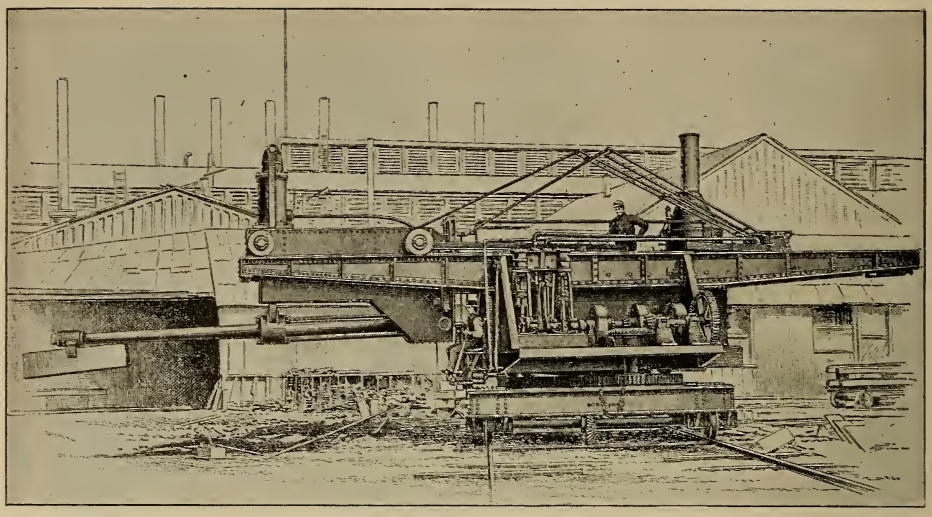
The original furnace boilers were plain cylinders, some of them 80 feet in length. Mud drums were added to these and the length of the boilers was shortened. In some districts double-return flue boilers are the prevailing type, and at a number of furnaces water tube boilers have been introduced. The preference, however, still is for the older type of boiler, and, as a rule, these are set with independent combustion chambers.

In short, the construction of the furnace stack or stacks, the hot blast stoves, boilers, blowing, hoisting and pumping engines, and the details of equipment must be carried out with an appreciation of the necessity of continuous operation, and the cost of delay or stoppage. The management of the plant must also be alive to the requirements of constant working and the possibility of even a slight repair resulting in very serious cost by its influence upon the operation of the furnace as a whole.

The grouping of a number of blast furnaces permits of liberal expenditures for general and detailed management, and at some of the larger plants this has resulted in securing ability of the highest order, through which remarkable records of output and fuel economy have been obtained. Exceptionally good work is not, however, confined to the blast furnaces of the larger steel plants, in some of which an appreciation of the importance of the smelting department seems to be wanting; in fact, the management of some of these fails of favorable comparison with that prevailing at individual blast furnaces of small or moderate capacity. The tendency to build furnaces of large capacity, or to group several under one management, may be expected to expand, but plants of but one or two stacks will continue to exist and challenge competition from others, more pretentious and with apparently increased advantages.



THE EDGAR THOMSON BLAST FURNACES AT PITTSBURGH, PA., FROM THE SOUTH.



A CHARGING MACHINE FOR A BLOOMING MILL.

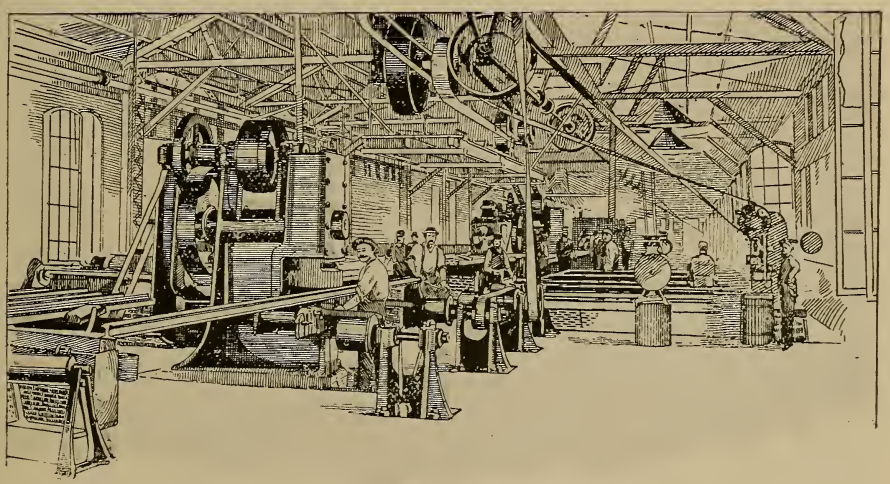
The radical differences evident in the blast furnace practice of the present time, when compared with that formerly believed to be most advantageous, are accounted for in a number of ways. When avenues of transportation were few, and when water-power was an essential for any industry of considerable size, a manufacturer of iron sought a location where power, ore and fuel could be obtained. As the fuel was principally charcoal, iron works were scattered upon streams, giving, by volume and fall, adequate power, and a site on such stream was selected as convenient as possible to a deposit of iron ore, and to woodland which would maintain a supply of charcoal. Some of these sites were so well chosen that, notwithstanding the exhaustion of the timber, the substitution of steam for water as a power, and sometimes in addition the exhaustion or abandonment of nearby ore mines, there are large modern iron industries now active and occupying the site of their early prototypes.

Scattered over wide areas, with but moderate facilities for communication, and with a limited literature to assist furnace managers, it is not surprising that greater advancement was not early recorded. On the other hand, the good sense and keen appreciation of all the surroundings which led to the selection of many excellent blast furnace sites, and the character of material which was produced, bear testimony to the business acumen of the constructors or operators of some of these plants.

The advent of canals and railroads, making it possible to assemble the materials for the production of iron at points nearer the market, drew the older iron works out from their hiding places in the mountains. As the use of mineral fuel spread, steam displaced water as a source of power, and as preliminary heating of the air before it entered the furnace became recognized as a feature of value, the size and capacity of blast furnaces increased, and with this came a livelier competition for available trade. This competition resulted in augmented pig iron production, and in a reduced cost of manufacture, which, combined, indicate true progress. In 1876, at the time of the Centennial Exposition, the United States produced less than two million tons of pig iron, valued at, say, forty million dollars. In 1893, when the Columbian Exposition was held, the pig iron output, although considerably less than it had been for five years, exceeded seven million tons, valued at one hundred

million dollars. In other words, while the pig iron product in 1876 was less than thirty per cent. of the volume of that of 1893, the total value of the output of 1876 was forty per cent. of that of 1893. Notwithstanding the improvement in equipment and management, the possibilities of blast furnace output have not been reached, although from one stack 13,000 long tons of pig iron have been taken in a month, and in one day the extraordinary output of 630 tons was obtained.

The story of how iron is made could be closed here, but the majority of those who read this contribution do not see iron in the shape of pig metal, and brief reference to some prominent methods of transforming it into merchantable shapes may be appreciated. All the pig iron which is reported in the statistics annually, does not attain the form of ingot or pig metal, for, as heretofore explained, the practice at some large steel works is to tap the iron from the blast furnaces into large ladles, carried on trucks, which are hauled by locomotives to and discharged into the steel converters, without allowing the metal to be molded and cast into the bars termed pigs. Still, the great bulk of iron made in blast furnaces is now cast into the form of pig metal for use in the foundry, and other industries. For foundry purposes the pig iron is melted in reverberatory furnaces or in cupolas into which it is fed in alternate layers with fuel, generally coke or anthracite coal, the molten metal being tapped into ladles from which it is poured into molds of varying form. For the production of steel where the direct transfer by ladles is not used, the pig iron is melted in cupolas and run into converters by troughs, or charged cold into large regenerative furnaces. To obtain wrought iron, the pig metal is placed in reverberatory furnaces, or into open charcoal fires, where it is melted and agitated until a crude ball is formed, which, by passing through a squeezer, or under a hammer, is roughly shaped, and which is recognized as a loupe or bloom. This bloom or loupe, when passed through rolls, becomes muck bar, or puddle bar, which is cut up and piled, often with scrap or other metal. The piles, after heating, are passed through other rolls, which produce billets, bars, skelp, shape, plate or sheet iron. In many cases several repetitions of reheatings and rolling are necessary to obtain a finished product. A small amount of pig iron is melted and decarburized in open coke or refinery



STRAIGHTENING RAILS.

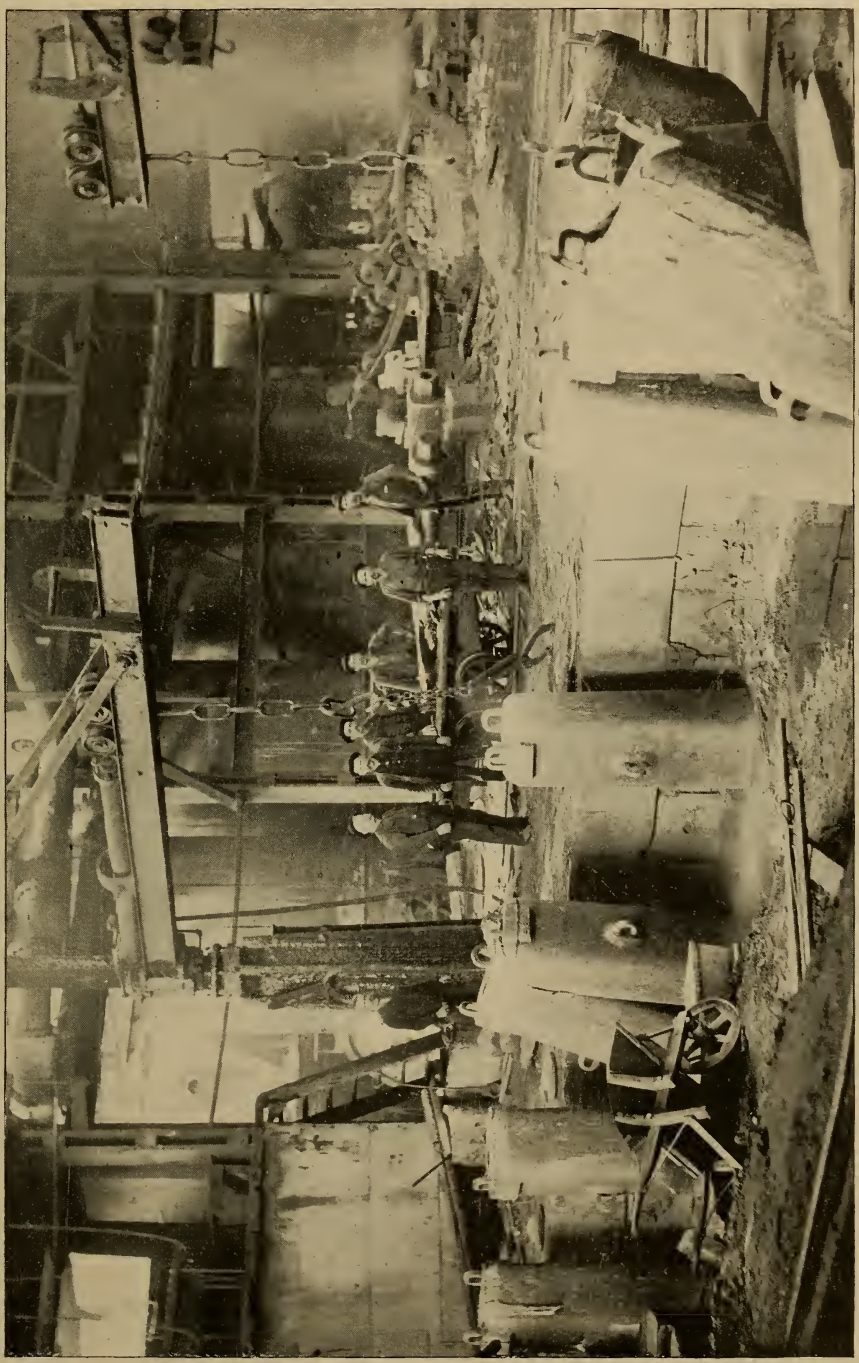
fires, the product, "run out metal," being subsequently treated in charcoal forge fires.

The forge fire, first alone, and subsequently in connection with the finery or "run-out fire," made the early wrought iron in this country, the blooms or loupes being hammered into anchovies and bars; for rolls were not employed until 1750, and those used at that time were merely to slit the iron into bars of approximately uniform dimensions. The puddling and subsequent rolling of iron in the United States dates from 1816, but heavy rolling, such as that of railway iron and railroad tee rails, has been practiced for but half a century.

The advancement indicated in blast furnace construction and operation is repeated in the appliances and methods employed in the production of wrought iron, for the rolling mill of the present time is in marked contrast with the slitting mill or the more ancient bloomaries or forges, a few of which still remain, the latter now being employed mainly for "sinking" scrap or working pig iron for special uses. A well-equipped modern rolling mill with gas producers, furnishing fuel to puddling and heating furnaces, the waste heat generating steam in boilers to propel machinery operating squeezers, hammers, rolls, shears, saws, and various mechanical devices to reduce the manual labor, produces also a much greater quantity of wrought iron, in better finished shape, than resulted from the efforts of a larger number of workmen for a week in a forge, the blowers and trip hammers of which received motion from water wheels.

The processes and methods in use at large steel works are even more advanced than those employed at many iron rolling mills, and since the manufacture of steel has assumed great proportions and exhibited marked economies, there have been numerous prophecies that "the puddling furnaces must go," and that in this "steel age" there is small prospect for development in iron manufacture. Although numerous inventions for producing steel in small quantities have been introduced, the results cannot be considered satisfactory, and present practice indicates that to manufacture steel economically it must (with the exception of crucible steel) be done on a liberal scale. On the other hand, the relative sizes of iron rolling mills does not affect to so great an extent the cost of production. In either case a large output is advantageous in reducing the fixed charges per ton of product, but the equipment for making steel must, in its prominent features, be of such proportions as to demand continuous operation and large output in order to accomplish satisfactory results.

In producing Bessemer steel, the molten metal is carried by steam power to converters into which air blast from powerful steam engines is introduced. After the silicon is reduced and the carbon is removed by the action of the blast, and the desired percentage of carbon has been added by the addition of ferro-manganese, the metal is poured from ladles into ingot molds, the converters, ladles, ingots and molds being handled by hydraulic power. The red-hot ingots are removed from the molds by hydraulic pushers, and are taken to heating furnaces from which they are subsequently withdrawn by mechanical means. These reheated ingots are delivered by carriers to blooming rolls, where they are reduced in size, and then pass through roughing and finishing rolls until the metal emerges as long bars of rail or beam section, ready to be cut into appropriate lengths by rapidly revolving saws. The finished metal passes by mechanical means to cooling beds, with the intervention of less manual labor than was formerly required for the production of one-tenth the weight of metal, and at a large saving in fuel. In some plants, ingots weighing as much as 3000 pounds are formed into large plates and heavy structural iron without the intervention of the blooming train. As illustrating the capacity of steel plants, it is of interest to note that one works has produced 45,500 tons of ingots in a month, and 38,000 long tons of rails have been the output of a rail mill in



INGOT MOLDS IN A CASTING PIT

the same time, 1950 long tons being the best record for a single turn, and 3590 tons for one day.

In the manufacture of armor plates and large guns, shafting for vessels, etc., the mechanical improvements and the general advance in steel manufacture is noticeable. In the works at Bethlehem, Pa., the pig iron is melted in open-hearth furnaces holding forty tons each, the metal being tapped from these into ladles and cast in molds, subjected, while in the molten state, to immense pressure, obtained through a system of pumps and accumulators. These castings are then passed through heating furnaces and formed to required shape in great hydraulic presses, or are worked under a hammer—the largest in the world—whose moving parts aggregate 125 tons. The superstructure of this hammer extends ninety feet from the floor, and its foundations start thirty feet below the same level. Cranes, capable of handling 300 tons each, convey immense masses of steel from the heating furnaces, and deposit them upon the anvil block—a pyramid of metal weighing 1800 tons. In the cylinder of this hammer, if it were laid horizontally on the ground, a tall man could stand upright, and it would require eight good strides to pass through it from end to end. A man's width at the shoulders would be no greater than the diameter of the piston rod whose length of forty feet would cause it to reach from the pavement to the roof of an ordinary house.

Heavy rails are now being sold in lengths of 60 feet, and some mills roll two or three of these rails in a single bar. Other mills produce I beams and channels 20 inches high. Boiler plate is rolled to widths of 10 feet, and is handled by electric cranes. To go into the details of the manufacture of iron and steel in the various ramifications would require volumes instead of pages. If the large and rapidly developing production of steel and its manipulations into various shapes even were admitted, the record of how the different forms in which iron constantly appears are made, would alone become a treatise. The puddling, shearing, piling, heating, rolling, reheating, rerolling, trimming, drawing, pickling, welding, stamping and straightening of different forms of wrought iron as bars, sheets, plates, wire blank, etc., each bring forward features of special interest. Similarly the casting of iron into simple or complex forms for light and heavy machinery, hardware, car wheels, etc., in which open or close, hard or soft, chilling or malleable castings are required offers too large a field of investigation to be covered in these articles. Hence it has been considered advisable to omit all but general reference to secondary forms, and to treat pig iron as the product in discussing "How Iron is Made."

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## RALPH HART TWEDDELL.

RALPH HART TWEDDELL, who has done more than any other man to further the application of hydraulic machinery to engineering work, was educated at Cheltenham College, one of the great English public schools. After devoting some years to classical study, he entered the modern department of the school, with a view of passing into the Royal Military Academy at Woolwich. However, he did not go up, and, instead, adopted civil engineering as his profession.

He entered the establishment of the Messrs. R. & W. Hawthorn, engineers, of Newcastle-on-Tyne, and while yet a pupil with them he took out his first patent in 1863, at the age of twenty, it being largely due to their encouragement and assistance that his attention was directed to that branch of

engineering which he has made so peculiarly his own. In 1865, his first stationary riveter was made and used by the firm of Thompson & Boyd, also of Newcastle, and he was now fairly started on that course which was to result in such great improvements in the methods of putting together all iron and steel structures. Up to the time spoken of, riveting had been done more or less wastefully and imperfectly by hand, gearing or steam, and it is owing to Mr. Tweddell's inventive genius and energy that this work is now accomplished in an economical, scientific, and almost perfect way by means of hydraulic machinery.

In the six years following 1865, many other leading firms adopted Mr. Tweddell's invention, and the whole subject of hydraulic machine tools and transmission of power by water was admirably presented by Mr. Tweddell himself in a letter "On the Application of Water Pressure to Machinery and Plant," which appeared in Engineering in 1871, and in which, among other things, he said:—"When we look around our large shipbuilding and engineering establishments, we find that they are measured as to their area by acres, and the distances over which the power given out by the engine has to be transmitted can be measured in a similar ratio. Such being the case, the transmission of power by shafting becomes both cumbrous and expensive, and this can only be partially remedied by having the engine power divided, and placed at different points, involving greatly increased expenditure of capital, extra labor, fuel, room, stores, and insurance. The waste of power, the loss of steam by radiation, and losses by friction in a large shipbuilding and engineering establishment is very great, and not creditable to our engineers and machine makers. It is useless, however, telling a patient of his ailments if you have not a remedy to propose, and the remedy to the state of matters slightly touched upon above is indicated by the title of this letter. For any class of machinery requiring power and a reciprocating motion only, there is no more direct means of obtaining these than by the use of hydraulic pressure. It has the least friction; it involves the smallest number of working parts; and is easily applied where wanted without gearing; hence, its convenience, one of its chief merits, while owing to the want of elasticity and other properties of water, the latter can be taken at a distant point from the first motion, or engine, with comparatively slight loss of useful effect.

"The hydraulic system is safe, and the pressure at which we can work is practically limited only by the mechanical difficulties arising from the smallness of the working parts then required, which renders the very high pressure unadvisable. Power is consumed only when work is to be done, for by means of the accumulator, or regulating reservoir, the power given out by the engine is stored up while the machines are idle, and is ready for distribution to them when they commence to work. If the system is to be adopted at all, we must take a broad view of it, and start from the commencement, by laying out our yards or works, as if we were surveying a town for gas or water supply, and put our pipes down by the side of our vessels, boilers or bridges, and from them branch out the smaller arteries wherewith to feed the individual machines, which will then do the work required and no more."

In July, 1872, Mr. Tweddell first brought his invention of the portable riveter before the Institution of Mechanical Engineers in a paper "On the Application of Water Pressure to Shop Tools and Mechanical Engineering Work," and it was not long before this historic paper was followed by the actual application, for the first time, of a portable riveter in the erection of a bridge *in situ*. This was done on the Primrose Street Railway Bridge, at London, in 1873, and proved a great success. No noisy hammering was to be heard. The hydraulic riveter did its work silently, but powerfully and swiftly. In one hour it rammed as

many rivets as could be driven in a day by a gang of hand-workers, and as it pressed the rivets into place while they were still hot and did not crack them by blows from a hammer, the work was much more evenly and strongly done than it would have been in the old way.

It was at this period that Messrs. Fielding and Platt, of Gloucester, undertook the manufacture of Mr. Tweddell's patent portable riveter. Since then their names have been closely identified with his in practically all the improvements and inventions involved in carrying into effect the methods of work, and labor saving appliances suggested by his experience and foresight. They now manufacture many other classes of these machines. Mr. Tweddell has frequently made public acknowledgment of their share and that of others in the development of the systems.

The next few years were devoted to experimenting with the early form of the portable riveter and improving it, and endeavoring to secure its general adoption in structural work, and in 1872-3 Mr. Tweddell established his present offices at London. The year 1876 may perhaps be said to have been the most epoch-making one in the development of what was by this time known as "Tweddell's system." That year witnessed the complete equipment of the Naval Dockyard at Toulon with hydraulic machines, and, at about the same time, Mr. Tweddell's apparatus was introduced to the American public at the Centennial Exhibition at Philadelphia. Owing, in the first place, to the initiative of his valued colleague, Mr. Henry Chapman, M. Inst. C. E., of Paris, the French Government took a very bold step, and by the advice of M. Marc Borrier Fontaine, their engineer, they were, in his words, "with the assistance of Mr. Ralph H. Tweddell of London, enabled to lay down works, the first, we believe, of their kind, where the plant consists exclusively of tools worked by hydraulic power, and where, consequently, there is no shafting." No one, accustomed to the noise of boiler and iron working shops, without visiting such an installation as that of Toulon, can form a just idea of the quietness of working of an hydraulically equipped plant.

At the Philadelphia Centennial Exhibition, Mr. Tweddell received an award for his patent, portable, hydraulic, riveting machine, "for originality of high order" and other merits. At the Paris Exposition of 1878, there was a very complete exhibit of his system, and, with the exception of Sir Joseph Whitworth, he was the only English engineer who received the *grand prix* for machine tools. Again, at the Inventions' Exhibition, at London, in 1885, the Society of Arts awarded him a special gold medal under the Howard Trust for his "system of hydraulic power applied to machine tools." Undoubtedly the portable hydraulic riveter attracts the popular imagination to the exclusion, perhaps, of his other inventions. There is nothing new in powerful, stationary, hydraulic machinery, but an hydraulic press working in mid-air was an inspiration, and to appreciate this, it is necessary to see machines exerting from 30 to 40 tons pressure several times a minute, suspended from cranes placed several hundred feet above river or ground level, and deriving their power through pipes looking like cobwebs, from accumulators, loaded to a pressure of 1500 pounds per square inch, many hundred yards distant. By such machinery all the largest bridges are now riveted in all parts of the world, among others, the Kistna Bridge, at Bezwadd, the Dufferin Bridge, at Benares, the Sukkar Bridge and the Tipra Bridges, in upper Central India, besides others in Egypt, Australia, the continent of Europe, the United States and Canada.

In connection with a syndicate of bridge builders, who tendered for the Forth Bridge, Mr. Tweddell was asked, in consequence of his previous successful applications, to get out designs for riveting this enormous structure. However, as is well known, Sir William Arrol obtained the contract for the whole structure, and his adoption of the hydraulic system and fertility of resource

in making many special applications are well known. This gigantic bridge could hardly have been built without the use of Mr. Tweddell's hydraulic system or some modifications of it. The whole work had to be riveted up, in place, piece by piece, and only the portable riveter could do this. The successful completion of this vast undertaking was indeed a triumph for hydraulic riveting. In addition to the value of hydraulic machinery in the building of bridges, it has been used with great success for riveting keels and other heavy parts of vessels, and all the largest steamers are riveted by its means where possible.

Besides his portable machine tools, Mr. Tweddell has invented many stationary machines, prominent among which are the large boiler riveters, exerting 150 tons pressure at each stroke. It is only by means of these that it has been possible to construct the latest types of marine boilers, carrying from 160 to 200 pounds pressure per square inch. Then, there is the hydraulic flanger, which with three hydraulic rams imitates hand work in an almost human manner; but each stroke of its paw means from 70 to 100 tons pressure.

The well known plate bending rolls are gradually abdicating in favor of hydraulic blocks and dies for bending plates cold. The advantages of hydraulic forging were advocated by Mr. Tweddell many years ago. He has, on his own account, and in conjunction with others, taken out some twenty-two patents in Great Britain alone. He is not himself a manufacturer, but it is a strong proof of the soundness of his inventions that some thirty to thirty-five firms in different parts of the world are now engaged—some of them largely—in the manufacture of machine tools on the system introduced by him thirty years ago. Without considering that in the absence of the help of these machines, some of the largest and heaviest work in the shape of bridges, ships and boilers could not have been accomplished at all, a very moderate estimate places the saving, by their use, in wages alone at a vast sum annually.

Commencing to invent while hardly more than a boy, Mr. Tweddell is in the position, at the age of fifty, of seeing all his earlier inventions common property and in universal use, but so mutually satisfactory, for upward of a quarter of a century, have been his relations with his co-patentees and manufacturers, that new patents are still being jointly taken out and find a larger market than ever, owing to the increased number of those now interested in getting the older types replaced or supplemented by new and more powerful machines. Mr. Tweddell has, in addition, a considerable general practice in Westminster, and his services as an expert and arbitrator are frequently requested. But hitherto he has been too busy a man to have time to spend in the law courts. He has read a large number of papers before various societies, and was awarded the first Telford medal and also the Telford premium for a paper read by him before the Institution of Civil Engineers during the session of 1882–3. He is a member of the British Institution of Civil Engineers, of the Societé des Ingenieurs Civils, of the American Society of Mechanical Engineers; and of the British Institution of Mechanical Engineers, of which last he was, until he resigned, a member of the council and of the research committee on riveted joints. He is a Justice of the Peace for the county of Kent, and resides at Meopham Court, near Gravesend. In conclusion, let him speak for himself: "All I can say is that I am a great believer in combining business and out-door sports. I have never found two days a fortnight with hounds 'lost' time, and I never miss a day's shooting or fishing if I can help it. This enables you to double the 'output' when at business, and still leaves many hours in the early morning for work as well." While acting up to this practice, there are few men who have worked harder or spared themselves less than Mr. Tweddell in the pursuit of their profession.

# HANDLING FLY-WHEELS.

*By M. N. MacLaren, Jr.*

IN erecting an engine of the Corliss type, putting in the fly-wheel often presents difficulties which are more or less ingeniously overcome by the man in charge of the work. Humble as the problem may appear, it is often quite perplexing, and much unnecessary labor, and, in some cases, broken fly-wheels, might be saved, by employing a few very simple methods. The safety of the wheel is, of course, the first thing to be considered, and the time and labor taken to erect the machinery is always next in importance.

In the following cases the writer has employed the methods described below with very gratifying results. To those experienced in this class of work the suggestions made may seem quite unnecessary, but it often happens that others are obliged to handle heavy machinery, and to them, it is hoped, these hints may be a help.

Most fly-wheels, whether belt wheels or balance wheels, up to a diameter of 20 feet and a weight perhaps of 15 tons, are cast in halves. The letter X in Fig. 1 locates approximately the centre of gravity of one of these halves.

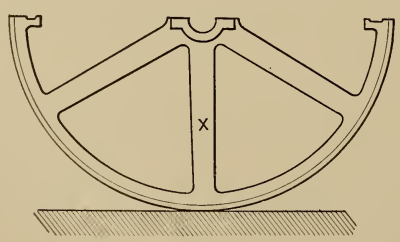


FIG. 1.

Therefore it will be seen that when the segment stands with the round side down, it is in a state of greater stability than with the round side up. In this position, then, it should always be moved when practicable, for it is not only less likely to tip over, but may be very conveniently slid along the greased planks, without the bother of skids and rollers.

The first and easiest case is when the pit is more than twice the width of the wheel. This obviates all difficulties

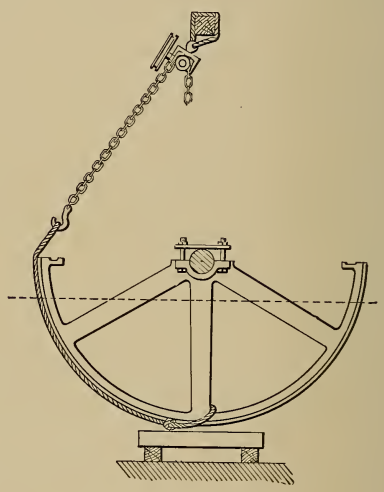

FIG. 2.

experienced by low ceilings. Timbers, supported on blocking, are laid over the pit, and both halves are successively slid, round side down, to their proper positions, and lowered, side by side, into the pit, and blocked just far enough down to clear the crank-shaft, when it is in position. This leaves everything above clear for the convenient handling of the crank-shaft, which is next raised by chain-blocks and lowered into its bearings.

One of the halves is then temporarily secured to the shaft by means of a large strap, or any suitable piece of iron, and two of the fly-wheel hub-bolts, as in Fig. 2. The blocking under this half

of the wheel is then taken out, and a line from the chain-blocks is carried around the face of the wheel, as shown in the figure, and fastened to the lowest arm of the segment. The half can then be very easily revolved about the shaft as a centre until it is in its proper position, viz., with the round side up and opposite the other segment, which remains in the pit. In case the ceiling is low, or the blocks become close hauled before the half is completely around, the segment can be quickly and easily blocked and a new hitch made. When the segment is once in position the chain-blocks secure it, and it is then jacked along the shaft until it comes directly over the opposite half.

In many cases, however, the pit is not wide enough to admit both halves of the wheel. When the ceiling is high enough to get a good hitch above, it is most convenient to place both halves in the position shown in Fig. 3. The first half is lowered into the pit with the round side down, as in the previous case; but the second half is turned with the round side up and rolled in on timbers or skids under the chain-blocks, where it is hoisted clear of everything, and high enough to allow the crank-shaft to be raised and swung into position by another pair of chain-blocks. Of course, if only one pair of chain-blocks is available, the top half may be lashed to the over-head timbers, and the same chain-blocks used for the shaft. After the shaft is in its bearings, the blocks are again transferred to the suspended half of the wheel, which is then lowered onto the shaft. In each of the preceding cases, the work of putting in a wheel is very rapid, and, even when the wheel is of large size, need not take longer than a few hours.

It often happens that neither of the above-described conditions exist. The pit may be narrow and the ceiling too low to admit of a hitch above for the upper half. In this case the lower half is lowered into the pit, as before described. But instead of taking the upper half of the wheel next, the shaft should be placed in position. Since there is no means of taking a hitch on the upper half, blocking and timbers must be laid on an incline from the floor to clear the shaft as it rests in its bearings. The segment is then rolled up this track on skids and lowered into position by jack-screws. Under these conditions, the putting in of a fly-wheel necessarily takes a longer time, but with a little forethought in the arrangement of

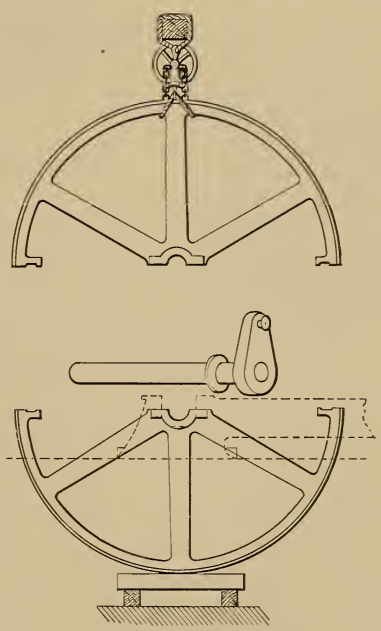

FIG. 3.

blocking and jacks, much unnecessary labor may be saved.

The cases above noted are most often met with, and in general, the methods described can always be used to advantage. The details may sometimes need to be altered slightly to suit varying conditions, as, for instance, using two pairs of chain-blocks where the wheel is heavier than the capacity of one, or where two roof beams are conveniently situated for over-head hitches, but where neither of them are directly above the bearings.

# Current Topics.

Do incandescent lamps start fires? A few very simple experiments that anyone can make will answer this question in a fairly conclusive way and will furnish an interesting demonstration of the extent of incandescent lamp fire risks under certain conditions. Those who lack the opportunity to make the trials for themselves will find the results which they undoubtedly would have obtained in a report submitted a short time ago to John Lindsay, chief of the St. Louis fire department, by A. J. O'Reilly, supervisor of city lighting. The investigation which Mr. O'Reilly made was prompted by a recent fire in that city, supposed to have been started by an incandescent lamp lying against a couple of wooden poles, and his conclusions, which have since been borne out by similar tests repeated several times, are decidedly to the effect that an incandescent lamp may, under favorable circumstances, cause a fire.

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WHERE the ignitible material was in a vertical position and the lighted lamp simply rested against it, Mr. O'Reilly found that in the case of white pine a spot, one inch in diameter and having a light brown color, appeared after about four hours. In the case of varnished oak, well seasoned, the varnish became blistered in three minutes and blackened in about fifteen minutes. The wood had the appearance of being charred at, and near, the point of contact, but was not ignited. A dry, white pine board began to smoke after forty minutes, but, through breaking of the lamp, the test stopped at that point. With a lamp incased in two thicknesses of muslin, the latter commenced to scorch in one minute, in three minutes gave off considerable smoke, and at the end of six minutes, when the muslin cover was removed from the lamp and fresh air reached its interior, it burst into flames. Where a lamp was laid on inflammable material, the effect seemed to be more rapid, due, probably, to the pressure exerted by the weight of the lamp. A newspaper was, in this way, carbonized in three minutes, and ignited in forty-five. The lamps used in the trials were all of 16 candle-power, and the results satisfied Mr. Lindsay, as they will probably satisfy many others, that fires may sometimes be very properly ascribed to what has generally been regarded as an absolutely safe form of light.

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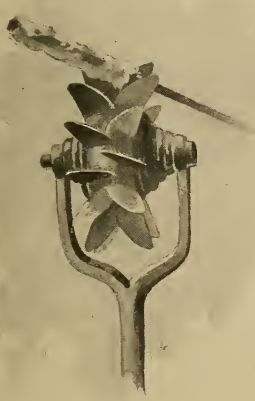
THE town of Kiew in Russia has a small electric street railroad, only about two miles long—the only one in that

country—which affords an admirable illustration of the appreciation with which gas engines meet in Continental Europe as compared with the more conservative tendencies of England and America. The plant at the power station consists of two generators, rated at 30 kilowatts each, and these are driven by two double-cylinder Otto gas engines through direct belt connection. Each of the engines is of 60 horse-power capacity, and runs at a speed of 140 revolutions per minute. The gas is furnished by the local works, and though no data are available on the subject it may fairly be inferred that the cost of operation is, in the main, satisfactory to those who have to bear it. Another feature of interest about the line has resulted from the fact that the operating company has been considerably annoyed by ice forming on the trolley wire, and to remove this the device shown in the annexed little sketch was designed, and has been used, apparently with good results. It has somewhat the appearance of a trolley wheel, though it does not, and is not intended to, serve the purpose of one, and is fitted up with cutting blades. A pole is attached to the harp, and with it an employee, who stands on the front platform of the car, holds the wheel against the trolley wire, exerting sufficient pressure to cut the ice.



REMOVING ICE FROM A TROLLEY WIRE.

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One of the most interesting modifications of water-raising machines, devised in the year 1746 by a Swiss tinplate worker named Wirtz, living in the town of Zurich, is described in some of the older works on hydraulics and pumping machinery. It has, not inaptly, been termed by some a spiral pump, and, according to Ewbank, was originally used to raise water for a dyehouse in the vicinity of its birth-place. What the circumstances were that led Wirtz to its invention is not told—whether it was suggested by some incident, or whether it was the result of reasoning alone. The machine consisted of either a helical or a spiral pipe. As a spiral, this pipe was arranged around the circumference of a cone or cylinder, and then resembled the worm of a still. The interior end was united by a watertight joint to the ascending pipe, while the open end of the coil was enlarged to form a scoop. When the machine, placed in water, as shown in the annexed sketch, was turned around to the left, the water in the scoop, as the latter emerged, passed along the pipe, driving the air before it into the rising pipe from which it escaped. At the next revolution both air and water entered the scoop, and the water was driven along the tube as before, but was separated from the first portion by a column of air of nearly equal length. By continuing the motion of the machine, another portion of water and another of air were introduced. The body of water in each coil had its ends horizontal, and the enclosed air was of about its natural density; but as the diameters of the coils diminished towards the centre, the water which occupied a semi-circle in the outer coil, would occupy more and more of the inner coils as they approached the centre, till there was a certain coil, of

THE WIRTZ SPIRAL PUMP.

which it occupied a complete turn. The pressure exerted by the column of water in one side of each coil was proportional to its length, and this pressure was transmitted, through the intervening column of air, to the next column; the combined pressure of both was then made to act, by the further revolution of the machine, on the third column, and so on, till the accumulated pressure of them all was communicated to the water in the delivery pipe, and, hence, the elevation to which the water could be raised could never exceed the sum of the altitudes of the several liquid columns in the coils.

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A MAN in France, who had received a severe shock from an electric current, and was, to all appearances, dead, was recently brought back to life by skillfully applied methods of resuscitation. This matter has attracted considerable attention, and most authorities now agree that in many cases, persons apparently killed by electricity may be revived by proper treatment. Dr. Augustin H. Goelet, in The Electrical World, gives a clear account of the method to be pursued. An electric shock may produce death in one of two ways, either by producing destructive tissue changes, when death is absolute, or by suddenly arresting the action of the respiratory and heart muscles through excitement of the nerve centres. In that case death is only apparent—in other words, animation is merely suspended. The patient may be aroused from this syncope if efforts at resuscitation are not too long delayed. The unfortunate person's condition may be likened to that of one in an exaggerated fainting fit, where there is necessity for prompt stimulation. The quickest and most powerful stimulant which can be employed is artificial respiration. The main thing is to make the patient breathe, and to do this it is best to proceed as follows:—The body must be placed upon the back. A roll, made of a coat or anything else convenient—rolled, not folded—should be placed under the shoulders, and should be sufficiently large to so prop up the spine as to drop the head backward. The operator should kneel behind the subject's head, facing him, grasp the elbows and draw them well over the head, so as to bring them almost together above it, and hold them there for two or three seconds. Then he should carry them down to the sides and front of the chest, firmly compressing it by throwing his weight upon them. After two or three seconds the arms should be again carried above the head and the same manœuvre should be repeated, at the rate of fifteen or sixteen times a minute. At the same time the tongue should be drawn out to free the throat. When the arms are extended over the head, the chest-walls are expanded, just as in inspiration, and, if the throat be clear, the air will rush into the lungs. When, on the other hand, the arms are brought down to the sides of the chest, compressing it, the air is expelled, just as in expiration.

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THIS, known as Sylvester's method, is the most convenient and reliable manner of inducing artificial respiration. The operator must, however, appreciate the fact that this manipulation must be executed with methodical deliberation, just as described, and never hurriedly, or half-heartedly. To grasp the arms and move them rapidly up and down, like a pump-handle, is both absurd and useless. If an assistant be at hand, the tongue, held by a cloth or handkerchief to prevent slipping, should be drawn forcibly out during the act of inspiration, or when the arms are extended above the head, and when the chest is compressed it may be allowed to recede. This rhythmical traction upon the tongue is, in itself, an excellent stimulant of respiration. It acts not only by freeing the throat of the tongue, which may fall back and obstruct breathing, but also by reflex irritation, through the fraenum, or bridle, under the tongue being drawn forcibly against the lower teeth. These efforts should be persisted in for at least one hour before giving up hope,

and the movements should be made carefully, energetically, and steadily. A person apparently drowned should be treated in very much the same way, and this fact may help to fix these directions in people's minds. As was said before, the great thing is to make the patient breathe.

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How to successfully utilize the power of ocean waves is a problem which has attracted attention for a great many years, and not a few of the latter-day appliances are but slightly modified imitations of what had been proposed and used generations ago. During a voyage from Stockholm to New York, more than forty years ago, a ship's master fixed a spar aloft, one end of which was ten or twelve feet above the top of the vessel's pumps, and the other projected over the stern. To each end was fixed a pulley. He then fastened a rope to the pump rods and after passing it through both pulleys along the spar, dropped it into the sea astern. To the rope he fastened a 110-gallon cask containing about 60 gallons of water. This cask answered as a balance weight, and every motion of the ship from the roll of the sea made the machinery work. When the stern descended, or when a sea raised the cask, the pump rods descended, and the contrary motion of the ship raised the rods and, with them, the water to be pumped. The arrangement, which, according to the available accounts, worked quite satisfactorily, is remarkably similar to more than one of the wave motors which have been put into service during the past half-dozen years.

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WITHIN the past ten or twelve years the uses of the hydraulic "Monitors" and "Little Giants" of California mining fame, as means of earth excavation, have become pretty well appreciated among engineers, and water jets have been successfully applied to a variety of engineering purposes for which only a short time previously they would never have been thought of. Pile driving with water jets, now so common, is only one modification of the general method, while the removal of heavy earth banks by these aqueous battering rams is another, which is deservedly working its way into favor. What has led to these reflections is a revised version, recently published, of an account of the removal, several years ago, of some river bluffs overhanging the tracks of one of the railroad lines in the western part of the

A HYDRAULIC MONITOR.

United States. This was accomplished almost wholly by the employment of jets of water under high pressure, bringing the cost of excavation down to the low figure of 1½ cents per cubic yard.

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IT recalls also a neat job carried out a few years ago in the way of filling in a large area of land just under water, and bringing it up to a level of several feet above the water line. Large sand hills ranged along the shore close by the shallows. The work got into the hands of two old California miners, who applied a modified hydraulic mining outfit to its execution. They bought a couple of large pumps, which delivered

water from the bay on the tops of the sand hills through an iron pipe, and then, by means of a series of boxes and sluices, they carried the dirt and sand which the water washed down from the hills out to the spot to be filled. In this way several acres of land were made at an expense which was merely nominal. The pumps and boiler were practically worth as much after the work was done as when they were first purchased ; handling of material with attendant cost there was none ; and the whole operation was completed in a remarkably short space of time.

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FLY-WHEEL accidents, resulting from engines running away, have latterly been a subject of considerable comment and have given renewed prominence to automatic and other stops designed to shut off steam and bring engines to rest before the danger limit is reached. Devices of this kind have been patented by the score, and the only reason perhaps, or at least the best one, that they are used so sparingly is found in their unreliability. To be worth having they ought to be certain in action, and this one requirement they meet only inadequately. A simple, effective and reliable stop is yet to be offered, and, if offered, would command a heavy sale.

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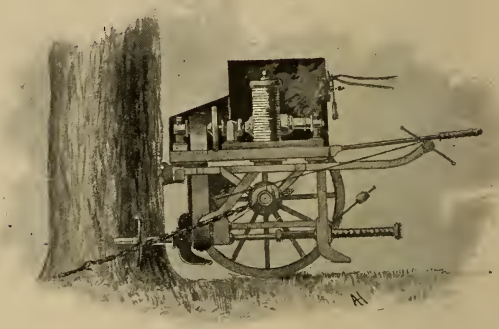
ANENT the steam tree-felling machine recently referred to in these pages, a correspondent directs attention to a similar piece of apparatus, worked electrically however, brought out some time ago by the well-known electrical engineers, Ganz & Co., of Budapest. What manner of machine it is the annexed sketch makes quite clear, requiring very little further explanation. Unlike the steam saw, there is, in this case, no saw proper, its place being taken by a form of drill which, according to the nature of the wood, may be used either to perforate the base of the tree with a number of holes, placed so close together that when the operation is completed nearly all the fibres have been cut through ; or it may be used to take a sweeping cut, the cutting edges being on the sides of the tool. This is the favored method. The machine is shackled to the tree to be brought down and a cut of suitable depth is taken across its surface by slowly rotating the driving motor, transmitting gears and drill on a common vertical



AN ELECTRIC TREE-FELLER.

spindle. This accomplished, the drill is advanced a few inches and a second cut is taken in the same manner until about half the thickness of the tree has been gone through. Clamps are then driven in to keep the cut from closing up by the weight of the tree, and the operation is continued until a point is reached where it would not be safe to cut away more wood. The shackling chains are then loosened and the machine is removed to a safe distance, after which the final separation of the tree from the stump is performed by a hand saw or axe.

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FOUR HUNDRED AND TWENTY-FOUR degrees Fahrenheit below zero ! Just what this means it is almost impossible to imagine, and, yet, it is one of the temperatures which have been reached and used in laboratory research, and has been made the subject of some highly interesting experiments and explanations by Professor Dewar before the British Royal Institution. Four hundred degrees below zero is not an every-day temperature, nor can it be reached by more every-day means than the expansion of liquid air, which

latter Professor Dewar has succeeded in producing in comparatively large quantities, and in storing by novel and ingenious methods, to be used, as required, in the study of matter at abnormally low temperature, exactly as a spirit lamp or a Bunsen burner is used in studying the properties of different bodies at the higher temperatures. One of the first points of importance brought out by Professor Dewar in one of his lectures on "The Scientific Uses of Liquid Air" was that in a high vacuum at that low temperature the difficulty of passing an electric spark in any form becomes almost insuperable. It would not be an extravagant inference from the phenomena were it affirmed that at the point of absolute zero, when the rarest gas known would have suffered condensation, electrical discharge through the frozen void would become altogether impossible. But there are constant warnings in physical science of the danger of pushing inference beyond experiment, at all events in regions where we are approaching the extreme limit of our resources. By enormously increasing its voltage, the current may be made to pass even through the frozen-out mercury vacuum; but the discharge assumes a totally different form, the diffused phosphorescence giving place to luminous streaks. It would seem, therefore, that after a certain degree of rarefaction has been attained, the gaseous molecules are no longer sufficient in number to act as carriers for an ordinary charge, while a more powerful one bridges the space only by the aid of the few that remain. The result almost justifies the presumption that ponderable matter is always necessary for the passage of electricity through space, but at the same time it opens up the question whether space can ever be wholly free of ponderable matter.

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Professor Dewar referred also to the effects of extreme cold on the cohesive power of metals. The tensile strength of iron at about 400 degrees below zero is just twice what it is at 60 degrees above. It will take a strain of 60 instead of 30 tons to the square inch, and equally curious results have come out as to the elongation of metals under these conditions. It was an idea of Faraday that the magnetism in a permanent magnet would be increased at very low temperatures, and experiments with comparative low temperatures had rather negatived Faraday's suggestion, but Professor Dewar has completely verified the opinion of the famous savant, having shown that a magnet at the extremely low temperature made possible by the liquid air, had its power increased by about 50 per cent. Very low temperature was shown also to have a remarkable effect upon the color of many bodies. For example, the brilliant scarlet of vermilion and mercuric iodide is reduced, under its influence, to a pale orange, the original color returning with the rise of the temperature. Blues, on the other hand, are unaffected by cold, and the effect is comparatively small upon organic coloring matters of all tints.

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Since the first appearance of the electric arc lamps, considerable effort has been expended in attempts to turn out a lamp in which the life of the electrodes, between which the arc is formed, would be longer than that of ordinary carbon burning in the open air. Various materials have been tried as substitutes for carbon, but nothing has yet been produced with which the result aimed at could be accomplished. From the fact that the ordinary direct-current arc lamp, as generally used to-day, burns about eight hours and then must be retrimmed, it will readily be seen that any device that would lengthen the life of the carbons would create a decided saving, not only in carbons but also in labor. It is all the more interesting, therefore, to note the several forms of so-called vacuum or air-tight arc lamps, which have, of late, made their appearance and some of which have apparently given promise of successful working. The principle

involved in the operation of these lamps is a very old and simple one, and it seems peculiar that it should have been neglected for so long a time. The peculiarity of these air-tight lamps consists simply in the fact that the arc is enclosed in a globe, or chamber, from which air is excluded, thus serving to lengthen the life of the burning carbon, because the disintegrating effect of atmospheric oxygen is, to a great extent, prevented.

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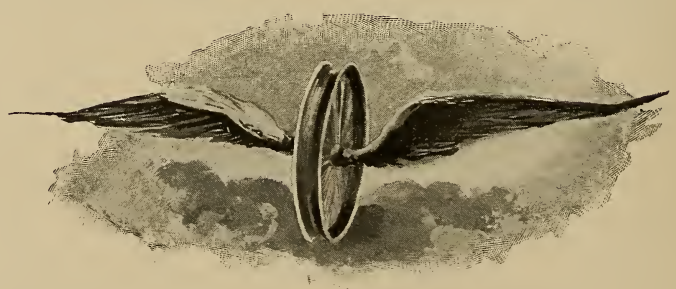
In one of the lamps of this type, recently brought out, there was a small glass globe which enclosed, besides the arc, only a small portion of the carbons. These passed through close-fitting covers in the top and bottom of the chamber. An automatic valve was provided to act when the pressure of the enclosed and heated gases reached a certain point. In another form, the entire carbons and carbon rods were enclosed in an air-tight chamber, leaving simply the regulating mechanism exposed. Still another type has appeared, in which two enclosing chambers are used. Neither of these is perfectly air-tight. An outer globe is provided which encloses a smaller globe surrounding the arc, and the apertures through which the carbons feed in the smaller globe are quite large and permit the carbons to move freely. The inner chamber acts as a rarified enclosure for the arc, while the outer globe serves as a reservoir for the gases coming from the inner globe. The outer globe is provided with a valve to permit the excess of gases to escape. These vacuum or rarified globe arc lamps seem to indicate a step in the right direction, unless the efficiency of the arc is impaired in them. One, not yet mentioned, advantage which they have is that with them a longer arc can be maintained, taking from seventy-five to eighty-five volts, enabling a single lamp to be connected and operated efficiently across ordinary incandescent circuits carrying from 105 to 115 volts.



Yours Truly
John Fritz

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# CASSIER'S MAGAZINE.

VOL. VII. FEBRUARY, 1895. No. 4.

## ELECTRICITY IN TEXTILE MANUFACTURING.

*By Dr. Louis Bell.*

IN no branch of modern industry is closer attention paid to economy and to every mechanical detail which goes to make up the commercial success of a manufacturing plant than in mill work as practiced to-day by the leading cotton and woolen manufacturing companies of America. Driven by the high cost of labor to seek every mechanical advantage that human ingenuity can suggest, the mill engineers of the United States are at once the most conservative and the most keen-sighted for improvements of any party of technical workers to be found. They are slow to act when new ideas are broached, but, having once made up their minds, carry out the work with the greatest sagacity and skill.

It thus happened that the electric motor found its way into manufacturing establishments of almost every kind before it was taken up by the textile industry, and perhaps this may be regarded as fortunate, for, as a matter of fact, the first cotton mill to adopt electric motors for the complete distribution of power throughout the plant, also took up the work in a very thorough and skillful manner, and left nothing undone to make a system as complete and perfect in its way as the system for the textile manufacture itself—and to say that is high praise, indeed. As a consequence, there is to-day in successful operation a perfect example of distribution of power throughout a large factory by electric motors exclusively, and, furthermore, by the most advanced type of electric motors, inasmuch as the three-phase system was chosen in the work and the induction motor is used throughout.

The plant in question is that of the Columbia Cotton Company at Columbia, in South Carolina—a corporation which, in spite of its Southern location, is backed by New England capital and made up of New England yankees, the president being Aretas Blood, of Manchester, N. H., long identified with manufacturing interests of various sorts. Lockwood, Greene & Co., of Boston, were the engineers of the projected mill, and after much deliberation, in consultation with Mr. S. B. Paine of the General Electric Company, they concluded to take the plunge which others had been contemplating at various times past and commit themselves irretrievably to the use of electric power in the operation of the mill.

The conditions were peculiar. The motive power was to be obtained from

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THE PLANT OF THE COLUMBIA COTTON CO., AT COLUMBIA, S. C.

the waters of the Congaree river, about half a mile from the city of Columbia proper. Owing to the topographical conditions, it was thought undesirable to place the mill directly on the river bank or, rather, upon the flat which one may, by courtesy, call a bank. To have so placed it, would have involved a great deal of trouble with foundations, a very undesirable location and considerable cramping of the territory available for extension. It therefore became necessary to place the mill in a suitable location and transmit the power to it from the water-wheels located close by the river banks.

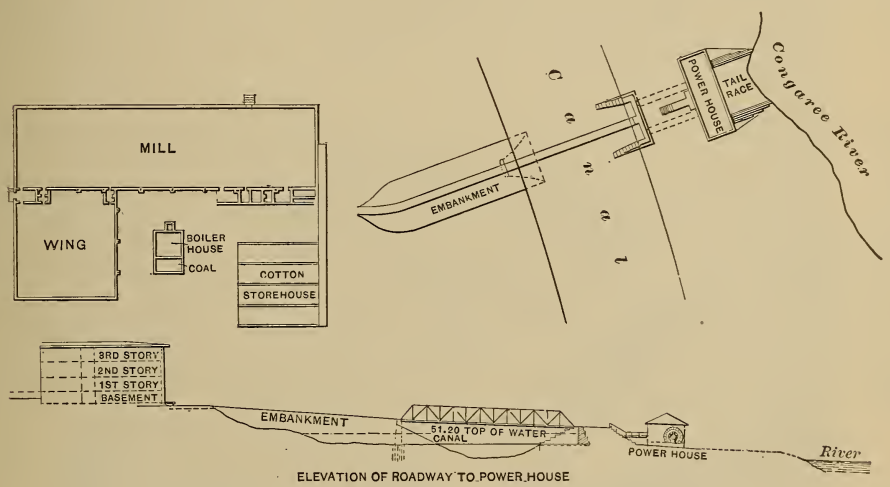
For this work the advantages of electrical power transmission were very marked. Instead of facing the alternative of a very indifferent and troublesome site for the mill on the one hand, or rather inefficient transmission on the other, it became possible to transmit the power very readily from the water-wheels to the mill, placed in any convenient location, and then to distribute it through the mill, not by the long, power-consuming lines of shafting generally found, but directly to each floor and room where power was needed, driving, in fact, short and light shafts of such size as convenience might dictate.

With this idea in mind, the projectors of the new enterprise cast about for apparatus, mindful of the fact that the electrical conditions to be met were most severe. In the first place, it was necessary that the efficiency of transmission should be very high—high enough to compare favorably with the delivery of the same power by the best mechanical means, otherwise no great advantage could be gained. Motors, dynamos and line must work together, so that the power lost would not be greater than that involved by a cable transmission and shafting throughout the mills.

More than this, the system must be so arranged that the speed of driving the machinery throughout the mill should be almost uniform, irrespective of conditions of load. So long as all the shafting in a mill is linked together mechanically, the variation in load on the whole is so slow and small that the speed can be held almost absolutely

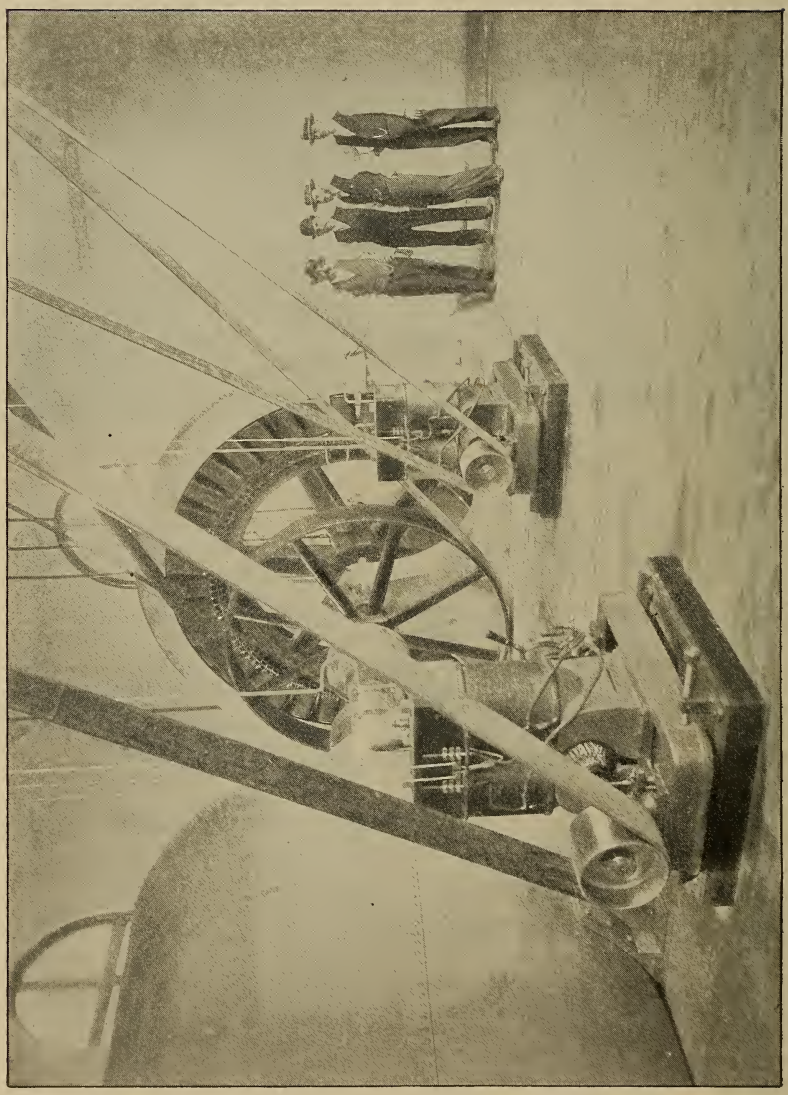
uniform. If, however, the new system of distribution by motors were to be adopted, each motor must be able to drive its shafting at a uniform speed while the variations in the load put upon it might be considerable and rather sudden. As is well known to engineers, the speed of cotton machinery must be held very close to uniformity in order to procure its proper operation, especially as to looms. Assuming, then, motor units of about 65 horse-power, the specifications were drawn with the provision that the variation in speed of the motor from friction load to full load should not exceed 3 per cent.; furthermore, it was regarded as very desirable to place these motors on the ceilings of the various rooms so as to save space for looms and to get the whole driving mechanism as much out of the way as possible; therefore, the motors had to be so arranged as to require almost no attention.

It was at this stage of affairs that the writer suggested the use of three-phase induction motors for the entire work. This was even more of an innovation than the electrical driving, for induction motors were almost unknown in the United States at the time, and their real capabilities were appreciated only by a handful of engineers who had investigated the subject. On looking into the matter carefully, the great simplicity and convenience of the motor without a commutator commended itself to the mill engineers, and the contract for the complete equipment of the mill on this basis was turned over to the General Electric Company. It involved the construction of two generating units suited for direct coupling to turbines at the very low speed of 108 revolutions per minute, each generator to be of 500 kilowatts capacity—the largest multiphase units that had been constructed anywhere, and, indeed, the largest that are now in operation. Connected to these were to be twenty 65 horse-power induction motors, arranged for overhead suspension, and built under the severe specification for speed variation just mentioned; in other words, it was necessary to build machinery of a character that had not anywhere yet been constructed and to beat the direct current motor at its own game. How successfully this task was accomplished can best be judged from the accompanying detailed description of the plant and its operation.




PLAN AND PROFILE SHOWING LOCATION OF MILL AND POWER HOUSE.

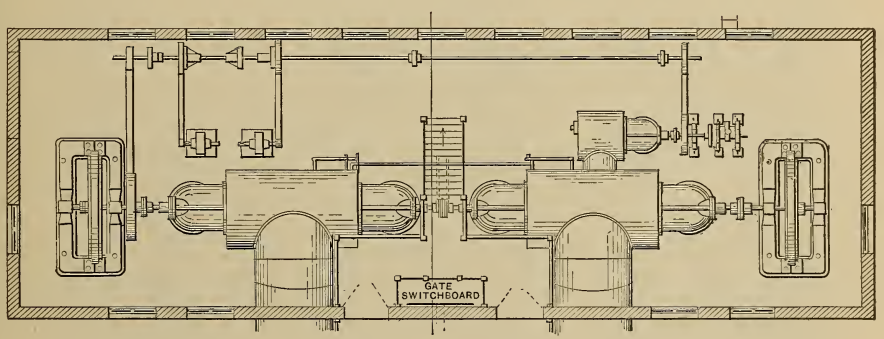
The plan and profile on page 277 show very clearly why the transmission of power became desirable. The nature of the ground between the further side



ONE OF THE 500-KILOWATT GENERATORS.

of the mill and the river is most undesirable, and the Congaree is liable, in any freshet, to rise so high that extreme precaution has to be taken in the power house to avoid its being flooded.

The photographic reproduction on page 276 gives an excellent idea of the general arrangement of the plant. The distance of transmission is very short, only a little over one-eighth of a mile. The water is brought through a canal of moderate length and of the approximate dimensions shown on the profile, and is delivered to two double horizontal turbines, each 48 inches in diameter, and enclosed in an iron casing. The working head is about 25 feet. Each turbine drives a 500 kilowatt 3-phase




PLAN OF POWER HOUSE.

generator from which the current is taken at an initial pressure of about 575 volts, and delivered to the motors at the mill without the intervention of transformers.

So much for the general arrangement. The details are somewhat as follows: The power house, the situation of which is plainly shown on page 277, is a one-story brick structure. It is 112 feet long, 38 feet wide, and is arranged as shown in the plan given herewith. The two turbines occupy the centre of the power house, and their shafts are permanently aligned and fitted with a positive coupling, so that, whenever desired, they can be run as a single unit. Such, indeed, is the customary method, as the two generators are then permanently in phase with each other without any necessary electrical connection.

To the right and left of the wheels are placed the two tri-phase generators, which are duplicates of each other. Each machine has forty poles, and revolves at the rate of 108 revolutions per minute, giving, therefore, about 36 complete cycles per second in the resulting current. The armature is 10 feet in diameter and is wound—although this word is rather a misnomer—with rods dove-tailed into insulated slots in the armature iron, and connected at the ends by massive curved straps of copper. Each slot in the armature contains but a single bar, and the whole structure is almost as solid as if it were a single casting instead of a built-up armature. The weight of each armature is about sixteen tons, and that of the complete machine a little over fifty tons.

The voltage, as before stated, is 575, and each machine is constructed with a safe working margin of capacity over and above the 500 kilowatts, which are its nominal output. Like nearly all alternators, these generators are separately excited, and for this purpose a bi-polar generator of about 20 kilowatts capacity is furnished for each machine, and is driven at the requisite speed by means of a countershaft and belting. These exciters are very much larger than would be required merely for the purpose of feeding the field magnets, for it was intended so to arrange the

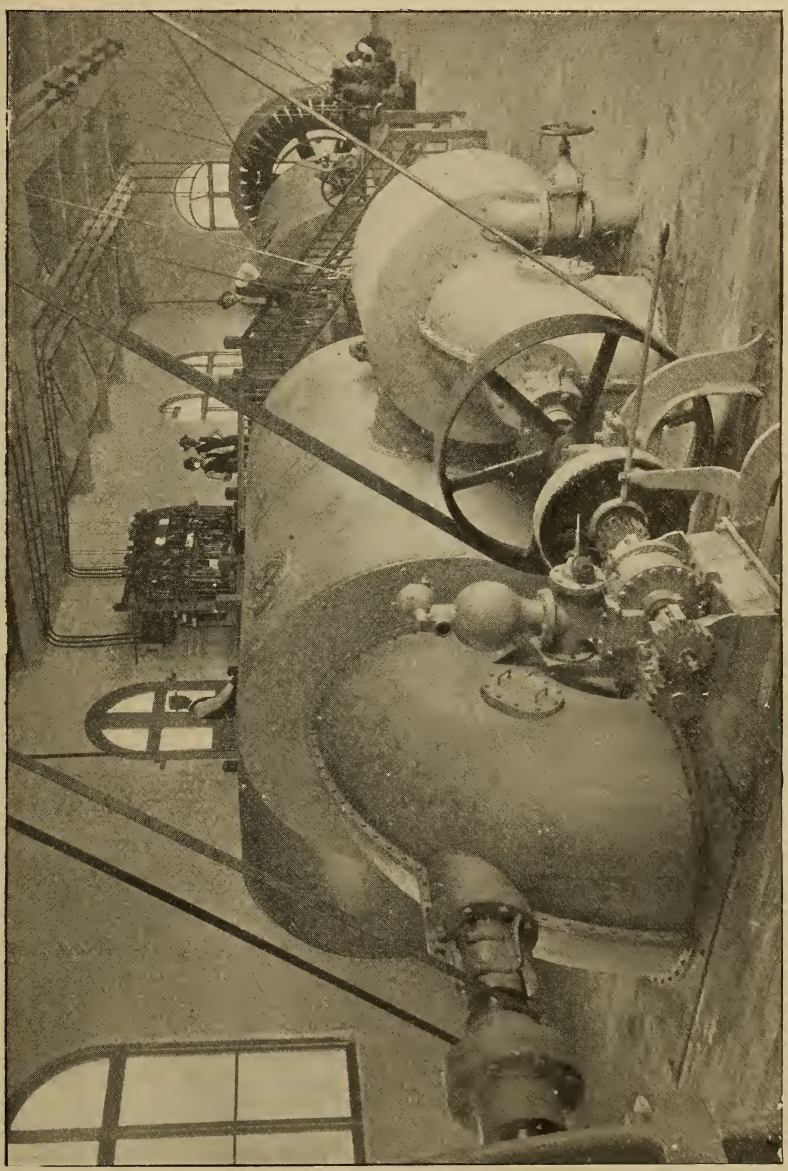
plant that either exciter could furnish current for the fields of both dynamos, and, in addition, have a sufficient output to operate lights and motors in the mill at night after the large machines were shut down. To this end, a single 24-inch horizontal turbine, shown in the figure, can be used for running the countershaft, as well as for driving a directly-connected fire-pump if necessary. The two large dynamos are habitually operated in parallel by the mechanical connection aforesaid, although means are provided for running them in parallel, with electrical connection only.

The cut on page 278 shows one of the 500-kilowatt generators in position with its exciter, while that on the page opposite shows the interior of the power house as viewed from a point near one end. The switchboard is on a raised platform, and consists of a skeleton frame, set out from the wall of the power house, so as to permit of ready access to the rear, and furnished with a complete set of instruments for each generator, as well as with the devices for throwing the two in parallel.

This completes the generating plant. The whole arrangement of it is singularly simple and straightforward, and was devised so as to require a very small amount of attention, one of the chief beauties of a water-power installation.

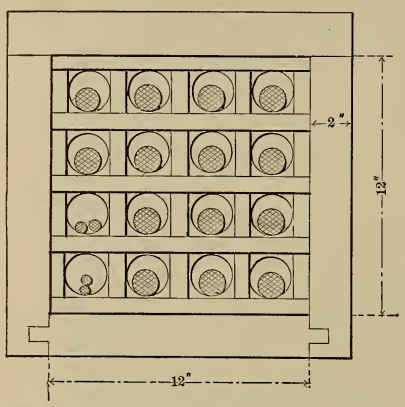
ANOTHER VIEW OF ONE OF THE BIG GENERATORS.

The line is of somewhat unusual construction. Both the nature of the ground and the large amount of copper required conspired to make an overhead line particularly unsightly and objectionable, so that, in the interest both of appearances and ultimate economy, it was decided to put the line per-



INTERIOR OF THE POWER HOUSE.

manently underground. This was, in itself, not an altogether easy task, but, once in place, the line should last indefinitely. The loss of energy in the line was limited to two per cent. in order to secure the necessary efficiency of the system, and the conductors were,

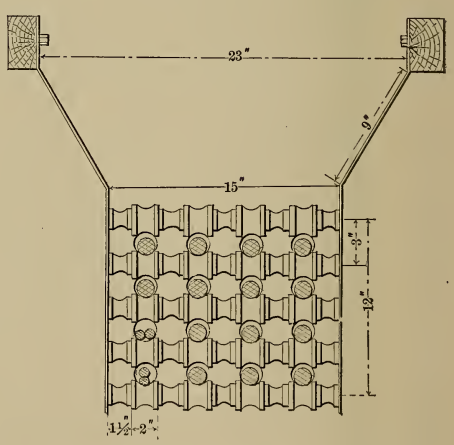



CROSS SECTION OF THE UNDERGROUND CONDUIT.

therefore, of very liberal cross section, exceeding even the specification. For each phase there were installed four cables, each of 450,000 circular mils. equivalent capacity. It was further desired to run incandescent lamps in certain parts of the mill at night when the main generators were shut down, and to operate a motor or two in the machine shop. For this purpose two No. 0000 cables were provided, and, in addition, there was installed a signal-bell circuit and a telephone circuit, each of twin-twisted cable. In all, sixteen separate cables were to be taken care of in the conduit.

This was accomplished in the following manner, illustrated in the diagram above: A massive, wooden conduit was constructed of 2-inch plank, 12 inches square on the inside and coated, like Noah's Ark, within and without, with pitch. About every three feet along this conduit a crib work was built up of insulating conduit tubing, as shown in the figure. Through the interstices of this crib work passed sixteen similar conduit tubes, 1½ inches in exterior diameter, and jointed so as to form sixteen continuous insulating tubes the whole length of the line. In these separate conduits were placed the sixteen cables, so arranged that the four cables of each phase were directly above one another for security against short circuits. The whole wooden conduit was then filled solid with pitch, melted and run in when the cables were laid. There was thus formed a solid mass of insulating material, sufficiently plastic to render cracking impossible, and absolutely impervious to moisture.

At the mill end of the line this construction is carried close to the mill, thence into it through a short brick conduit laid in Portland cement. At the other end of the line the bridge over the canal must be crossed. At the end of the wooden conduit, as it comes out under the bridge, the cables in their enclosing conduit tubes are sealed in with sulphur, run in for about 2 feet along the main conduit. The separate tubes are then taken across under the bridge, resting on porcelain insulators, strung on the iron structure




FRAME FOR CARRYING CONDUIT TUBES.

shown here. After the bridge is passed the box conduit is resumed, and the wires pass on to the power house. The line is thus described in detail on account of its decidedly unusual character. It is put in place to stay, and it would be most extraordinary if there should be any signs of leakage or a

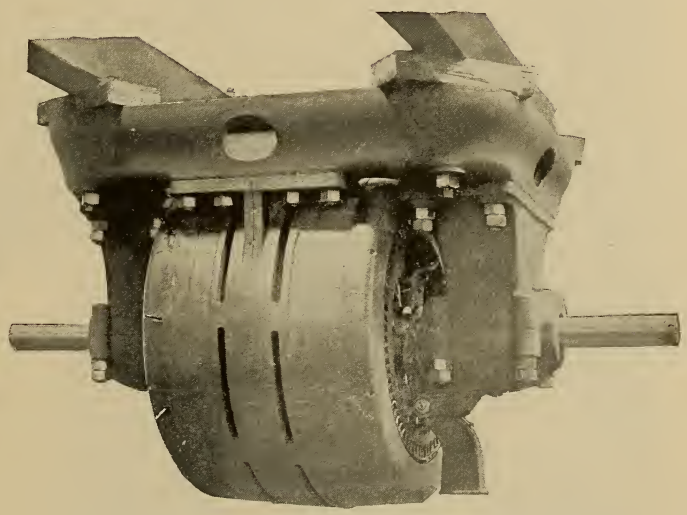
short circuit in a structure so constituted.

In the basement of the mill the conductors come out into a small brick room, whence the distribution conduits pass out over the mill, and where are installed the transformers for lighting the mill at times when the large generators are in operation. Eight hundred lights are installed in the building, the distribution being at 110 volts on the Edison three-wire system.

Having led the current safely to the mill, we may now take up the question of the motors and the somewhat extra-

feet above the floor. Each motor is provided with a separate glass-faced box, containing the switch and fuse box. These boxes are placed on the nearest post, and the risers run directly into them.

There are seventeen of these motors now in place, and three others are ready to be installed as the load grows heavier. The overhead shafting is light and arranged in short lengths. Two of the motors, those in the picker room, are direct coupled to the shafting ; the others are fitted with two or four pulleys each, driving their appro-



ONE OF THE TRI-PHASE 65-HORSE-POWER CEILING MOTORS.

ordinary arrangements pertaining to them. The use of conduit tubing is continued throughout the mill, the risers being of brass-sheathed conduit. The motors installed in the mill have a nominal output of 65 horse-power each, and are of the three-phase induction type, without commutators or collecting rings of any sort, a point of special advantage in cotton mills on account of the amount of stray cotton fibre liable to float around in the atmosphere, and to become a source of danger from fire if sparks are at hand. The motors are uniform in size, and are all arranged to be suspended from the ceiling of the mill, from 10 to 16

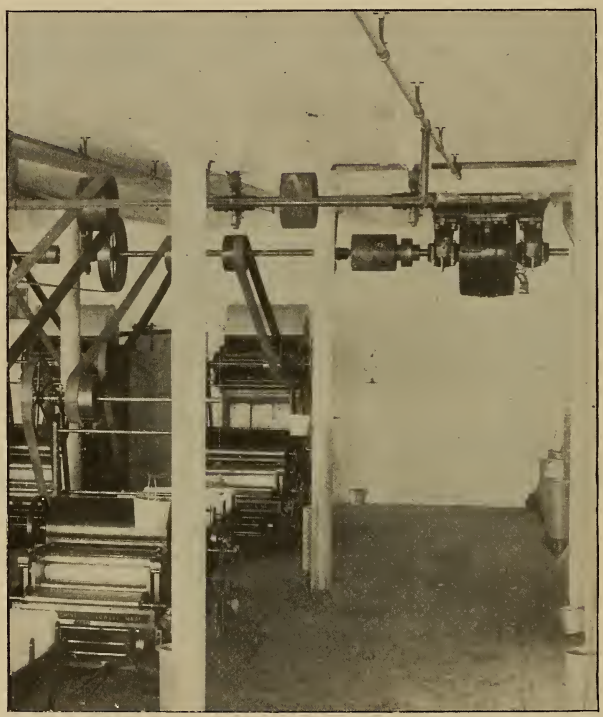
priate sections of shaft. Where four pulleys are used, belts are taken both ways at each end of the motor, so that there is no twisting moment on the suspension of the motor. Where two pulleys are used, these are generally placed at the same end of the motor, thus securing the same advantage.

The speed of the motors is the same in all cases—about 535 revolutions per minute. The variation in speed from friction load to full load was, according to specifications, not to exceed 3 per cent. As a matter of fact, the greatest variation in any individual motor was 2.2 per cent., and in the various motors from that figure down to 1½ per cent.

The motors are all fitted with resistances, placed within the armature spider. These resistances are used only in starting, and are cut out after the motor is nearly at speed by inserting a long lever into a socket and sliding a ring along the armature shaft until it short-circuits the resistance coils. These resistances are adjusted so as to start the motors on considerably less than their normal running current.

By the arrangement of motors just described all the parts of the mill are driven independently—sometimes a great convenience ; all heavy shafting and belting is dispensed with, the whole floor space is available, there are no apertures for belts from floor to floor, and the whole arrangement is of the most simple and flexible character. The net efficiency of the whole system, from the shaft of the generator to the shaft of the motor, is not less than 82 per cent.—a figure considerably in excess of anything which could be obtained from the power house to the working shafts by any other known system of driving.

As to the actual operation of the plant, it has now been working steadily for over eight months without the slightest mishap and with singularly little attention, more than fulfilling both the guarantee made and the hopes of the mill engineers. It furnishes at once the largest multiphase plant now in operation, and the first sweeping application of the electric motor for driving machinery for textile manufacturing. It not only is a thoroughly successful specimen of electrical distribution of power, but a complete demonstration of the excellence of the multiphase system for power distribution aside from all questions of transmission. As such it certainly deserves the careful description which the writer has endeavored to give.



A CEILING MOTOR IN POSITION.

# RECENT AMERICAN DIRECT-CONNECTED ENGINES AND DYNAMOS.

*By Thos. G. Smith, Jr., M. E.*

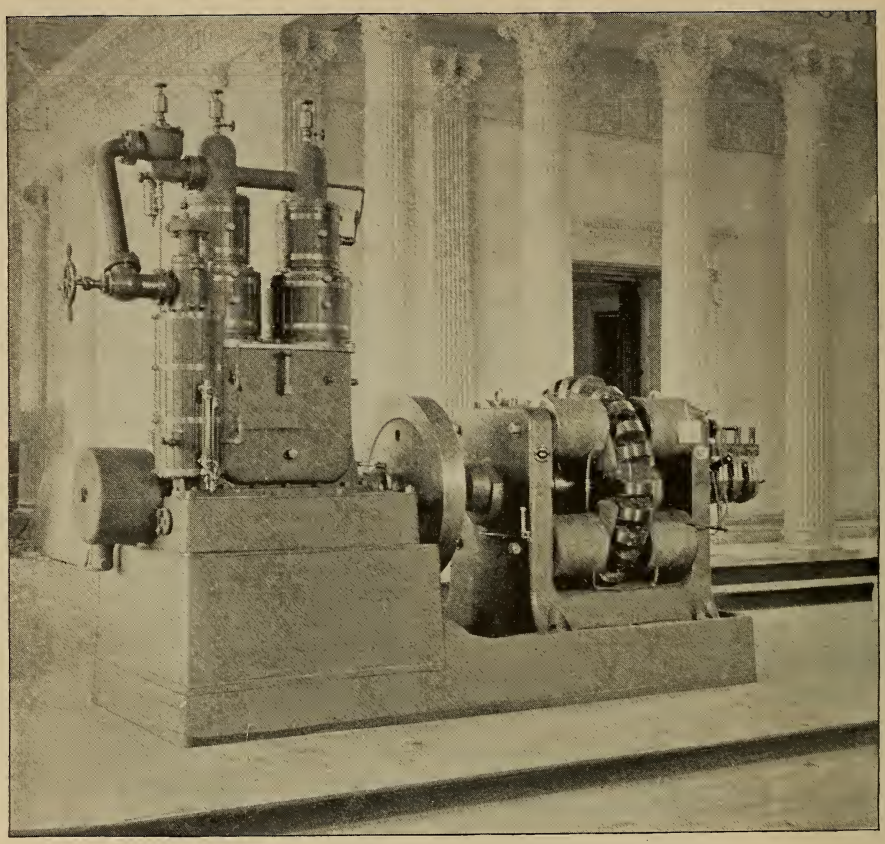
THE question of the most economical and satisfactory method of transmitting power from engines to dynamos has occupied the attention of engineers ever since the introduction of electric lighting on a practical scale. That method best meets the requirements of the case which does away with every detail that can possibly be spared without adding new sources of care and uncertainty. In large cities, where real estate commands high prices, and particularly in buildings requiring a variety of service, it is of the highest importance that attention be paid to cutting out all "dead wood," all sources of waste, and every detail which adds in any way to the care and expense of maintenance.

Thus have engineers been brought to the earnest consideration of how best to transmit the power required from the prime mover, be it engine, water wheel, or other source, to the dynamo for the production of light and power. A method now coming into general use, of which much is expected, is mounting the dynamo directly on the shaft of the engine, virtually making it take the place, in part, of the fly-wheel, and forming, in combination, one simple piece of mechanism.

With this we have the least possible amount of space occupied for the power; everything so disposed as to be under the eye and hand of the operator, and subject to most easy control. There are no extra bearings to look after, no clutches, couplings, belts or other of the infinite details that we have been accustomed to inspect and care for, and which seemed so absolutely essential to the proper equipment of all plants. In what other manner would it be possible so to dispose power and load as to secure more intimate and absolute control, and greater freedom from chance of accidental derangement of parts? By what other arrangement could we successfully crowd into modern buildings all the various pieces of mechanism, so necessary to the present luxurious mode of existence?

It has been claimed, with a great degree of persistence, by the advocates of slow-speed engines and countershaft transmission, that we were making our plants liable to serious disability by concentrating power in large, direct-connected units; that the engines would not be able to stand the severe strains incident to sudden overloads and short-circuits; and that an accident to one unit would cause extravagant delays and greater damage than would be possible with the other method of distribution.

This criticism, however, will not hold good, in view of the perfection of modern construction, and the fact that with direct-connected units matters have been so simplified, that we are under most favorable conditions for steady, continuous service, with fewer elements of chance of failure. A short-circuit, which would throw a main belt, wreck a main clutch, or burn out one or more



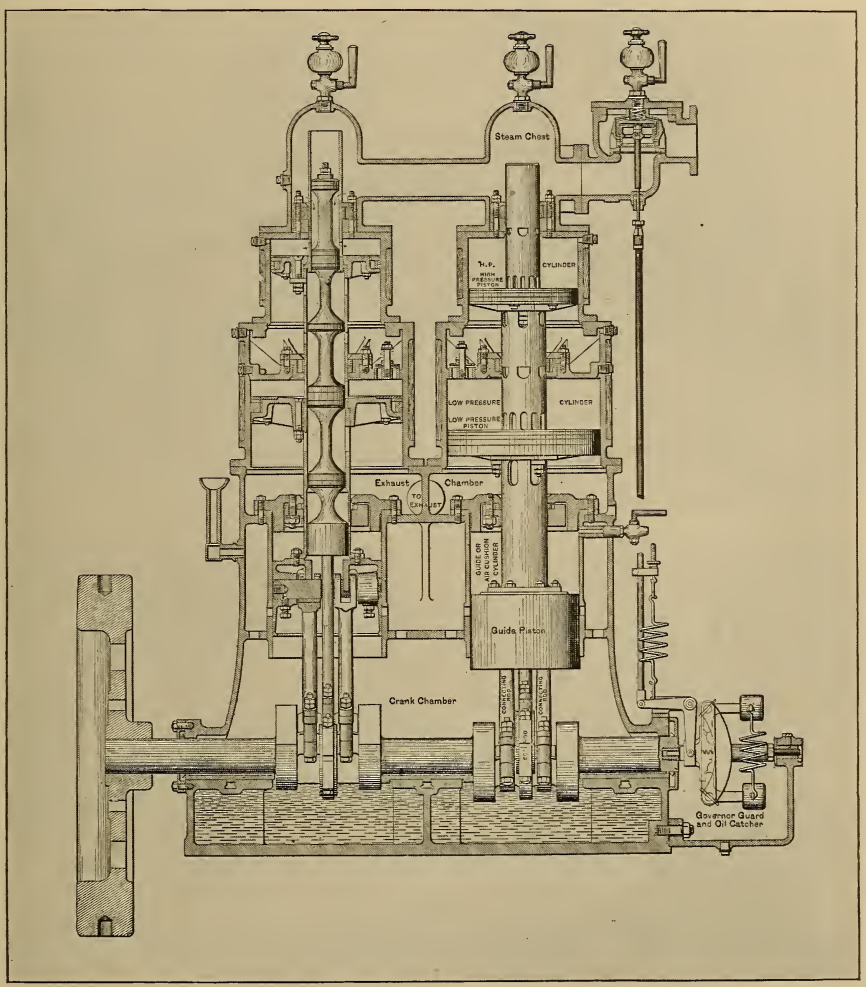
THE WILLANS ENGINE AT THE CHICAGO FAIR.

small-belted units, would, at the worst, only slow down or stall the direct-connected unit. Aside from this, consider for a moment the endless amount of care and attention demanded by the belts, bearings, clutches and tension devices incident to the system of employing slow-speed engines with counter-shafts and small units in generators.

The value of any method of transmission may be judged from a study of its characteristics, and a comparison with others, with a view to determine in what degree it possesses the following features : Economy, flexibility, close regulation, durability and reliability. As to the question of economy, we might assume that, whatever the conditions of the case, the method which dispensed with intermediate mechanism, without adding anything to consume extra power, would produce results most desirable.

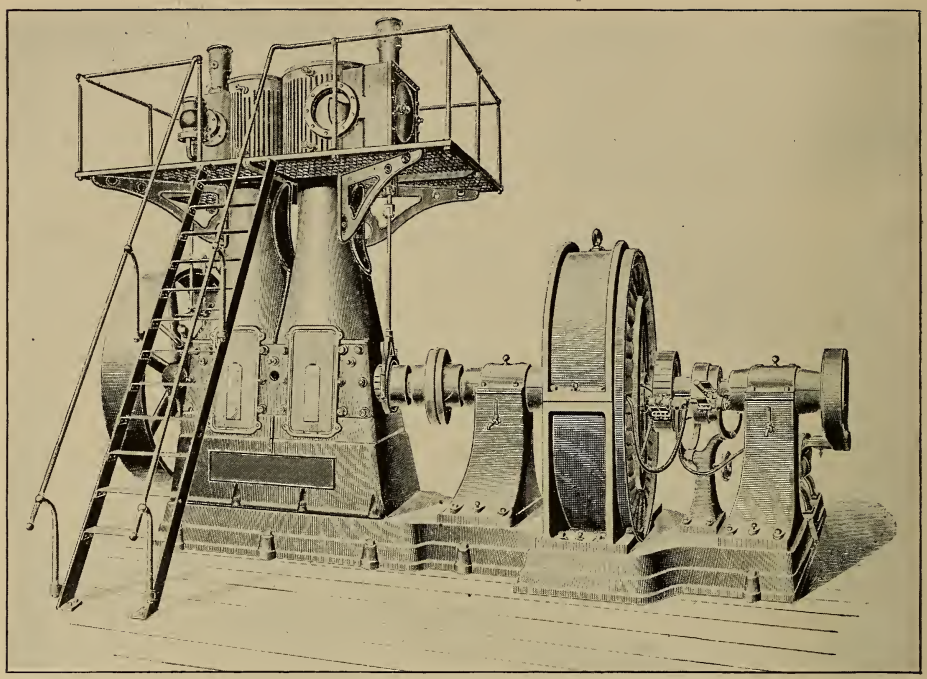
The question of first cost often determines the plan to be pursued in laying out and equipping a station. Let us assume that, for single units of equal power, the costs of both engine and generator for direct connection are greater than for belting ; on the other hand, where one direct-connected unit takes the place of several smaller-belted units, we find that the costs of both engines and generators are less per horse-power. The cost of the main belt alone, in large installations, will about offset the cost of fitting the engine for direct connection, and all extra belts are dispensed with. The cost of foundations is certainly less for the com-

bined unit, as there are none to be provided for counter-shaft bearings. The cost of counter-shafts, bearings, pulleys, belts, clutches and shifting-rigs is all done away with, and this cost is considerable in a large station. The spaces occupied in the two systems differ considerably, the direct-connected unit taking up only a small part of the room necessary for even belting direct from engine to generator.




SECTION OF THE WILLANS CENTRAL VALVE COMPOUND ENGINE.

In cost of operation we find the balance much in favor of direct connection. Attendance, supplies and every item going to make up this cost are reduced very considerably. One item of expense in the conduct of a station, which has a marked effect upon the economy, is the cost of maintenance. Every detail liable to wear, get out of adjustment, or require renewal at intervals adds its quota to the general cost, and it is in the removal of most of these smaller sources of expense that the direct-connected unit has shown marked superiority over former methods. Belts wear out, stretch and require constant adjustment; counter-shaft bearings must



VERTICAL COMPOUND ENGINE, BUILT BY THE BALL ENGINE CO., ERIE, PA.

be rebabbited frequently ; clutches demand readjustment and renewals ; shafts must be carefully watched and kept in alignment ; a multiplicity of oil-cups need constant cleaning and repairs.

But it may be asked—does the direct-connected engine and dynamo constitute a unit with sufficient flexibility? Is it not too rigid and subject to greater damage from excessive changes of load? To the first question we answer emphatically yes ; to the second, no. In modern stations, the load is not so divided that we are compelled to have small units ready to throw in or out as the load varies ; the economy of operation of the direct-connected unit is so good, from reasonably light to considerable overload, that we are enabled to cover a wider range of load, and still avoid the constant, wasteful demands of counter-shaft connection. Now that we are able to run arc and incandescent lights and power from the same generators, with practical success and economy, there is no necessity of having generators of various kinds to meet the requirements of the service. From the construction of modern direct-connected generators, we are safe in relying upon freedom from all the ills incident to the older, small, very high speed machines.

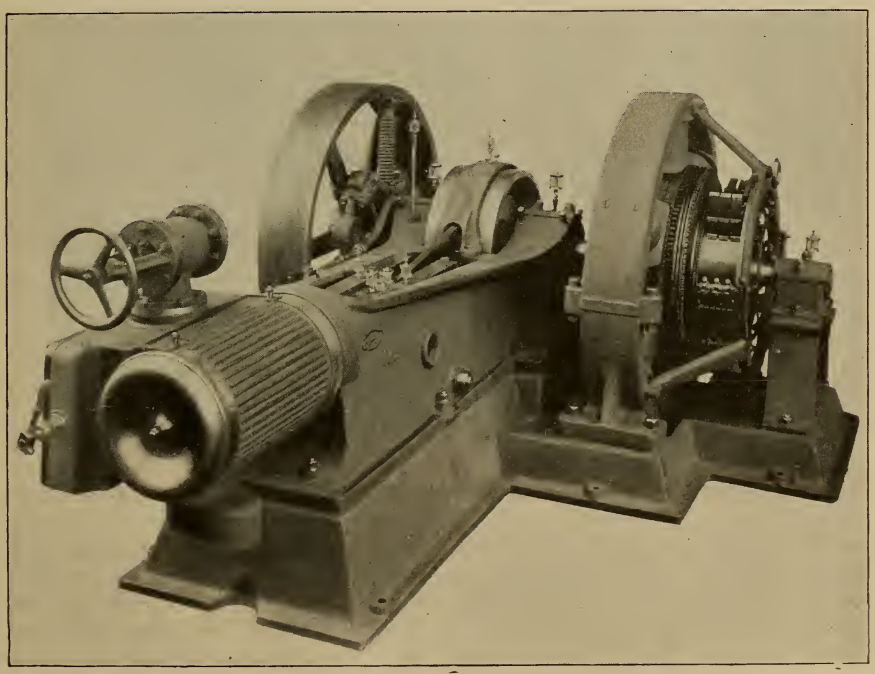
The reliance placed in the flexibility of belt connection has been proven by later experience to be somewhat of a delusion. What better cushion to absorb shocks and take up variations of load could be desired than the steam in the engine cylinder, combined with the stored energy of the fly-wheel and dynamo armature? By mounting the armature on the engine shaft, and doing away with all intermediate gearing, the variations are transmitted directly to the elastic steam cushion. Every joint, bearing, belt or other intermediate device tends to prevent a prompt response to change of load. It has been found impossible, in fact, to satisfactorily maintain the voltage with belted units, while it is perfectly practical to do so with direct-connected ones. This is

most clearly demonstrated with extreme light loads, where the reactive effect of the belt is most noticeable, causing a wide variation.

It has been further demonstrated by observation of two units of the same capacity, operating side by side in a station—one belted, the other direct-connected—that in every case the direct-connected unit met changes more promptly, maintained the voltage practically constant, and gave a much more uniform current. It also kept in advance of the belted unit, carrying its full share of the load at all times. There seems to be no way out of the conclusion that the direct-connected units regulate more closely under all conditions of load.

With a belted generator, under light loads, the belt is not under sufficient stress, at all times, to support its own weight, and there is a surging of the belt in a vertical direction, which causes a variable speed of the generator armature even with practically constant speed of the driving pulley. The effect of this belt reaction, in conjunction with any lost motion in intermediate connections, is fatal to close regulation in plants of the belted type.

While direct-connected units have not been used sufficiently long to convince all persons interested in these matters, still the writer is led to believe, from what has been demonstrated by actual practice, that most satisfactory results may be expected from this combination, considered from whatever point of view. The construction of the elements of the latest units is heavy and substantial; the arrangement of parts is compact; and every indication tends to justify the expectation of excellent performances. The simplicity of construction, small number of parts liable to derangement, the perfection of workmanship and materials, and above all the flattering success of units already installed, encourage the belief that marked progress has been made in the art, and that in the direct-connected engine and generator we have a system of transmission which embodies the



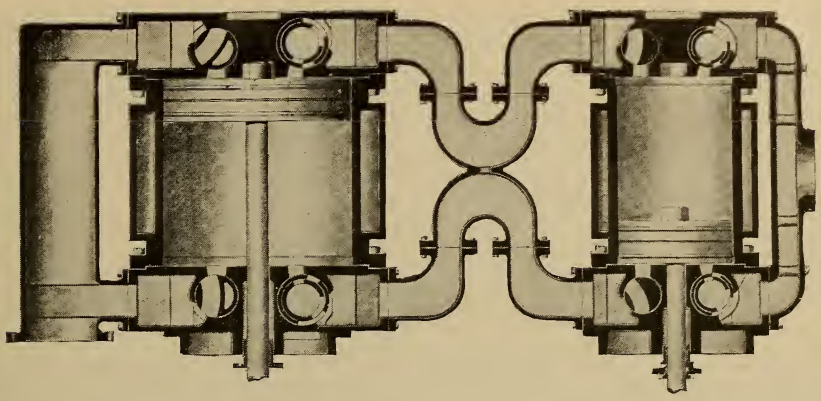
A WOODBURY DIRECT-CONNECTED ENGINE, BUILT BY THE STEARNS MFG. CO., ERIE, PA.

requisite features of economy, flexibility, regulation, durability and reliability, in a most desirable degree.

It may not be uninteresting here to show some of the latest direct-connected designs from which the prospective buyer of an engine and dynamo outfit may choose. Their name might be said to be almost legion, and additions are constantly being made to the list, so that obviously only a relatively small number can be given space in these pages.

Perhaps one of the most striking of the engines now used in combinations of this kind is an English one, turned out originally by Messrs. Willans & Robinson of London, by whom it is still being built, and known as the Willans central valve engine. It is now, however, being put on the American market also by the M. C. Bullock Manufacturing Company of Chicago, Ill. The engine is of the single-acting type, all the moving parts being in constant thrust, as in all engines of this

VERTICAL COMPOUND ENGINE, BUILT BY THE BALL & WOOD CO., NEW YORK.



SECTION THROUGH THE CYLINDERS OF THE BALL VERTICAL ENGINE.

kind, so that, however loosely the boxes may be run, the same portions of the connections are held against the crank and wrist-pins, and no knocking ensues as where the connecting rod is subjected to an alternate thrust and pull. In order to prevent the relaxation of pressure between the pins and rod by momentum acquired on the upward stroke, they are subjected to compression, not by retaining steam in the cylinder and thus reducing the effective area of the steam diagram, but by the compression of air by the guide piston, in a manner apparent from the sectional view on page 287. At the bottom of the chamber above the guide piston are ports, which are open to the atmosphere when the piston is in its lowest position. The first upward movement of the piston closes these ports, and compression commences always at atmospheric pressure, whatever the counter pressure in the steam cylinder may be. The air, thus compressed, reacts to assist the movement of the pistons on the downward stroke.

The engine is made with two or more sets of cranks and pistons, each line of pistons being connected to its corresponding crank by two exactly similar connecting rods, in the space between which works an eccentric, forged solid with the crank-pin. The eccentric is upon the crank-pin instead of the shaft because the valve face (*i. e.*, the inside surface of the hollow piston rod) moves with the pistons. Placing the eccentric upon the crank gives its centre the same motion as the valve seat, reduces their relative motion to zero, and allows the eccentric to operate the valve with reference to the ports in the same manner as when the ports are stationary and the eccentric turns about a fixed point.

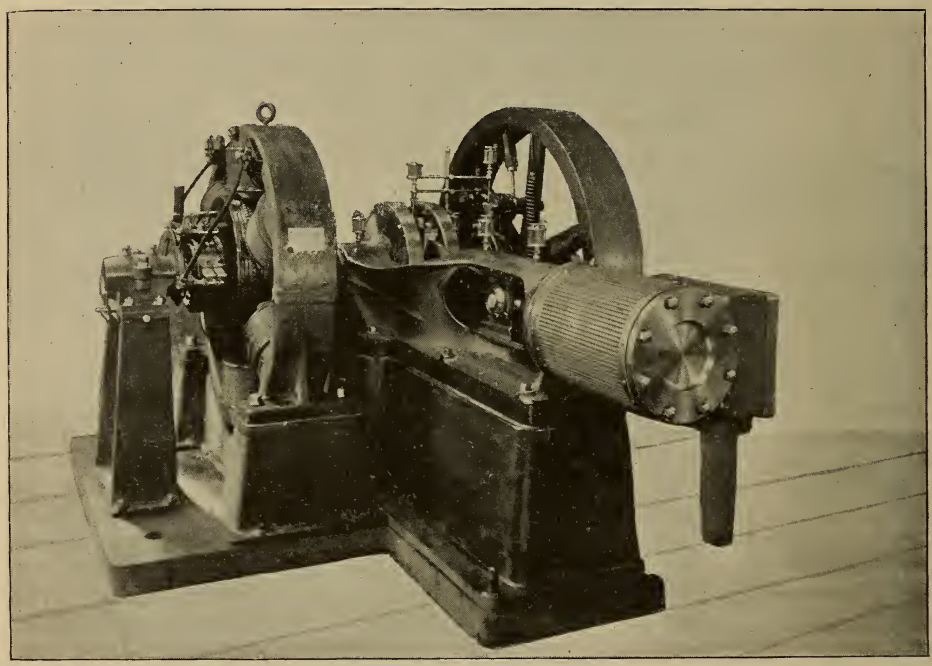
Piston valves are used, moving inside a hollow piston rod which passes completely through the line of pistons and through the ends of the cylinders. In the sectional view the pistons at the left are upon their downward, those at the right upon their upward stroke. Steam enters the high-pressure cylinder from the chest on top through the narrow portion of the upper valve, as indicated by the arrows, and is exhausted, as shown by the high-pressure cylinder at the right, through the hollow piston rod into the space below the high-pressure cylinder. From this space it is admitted to the low-pressure cylinder, as shown at the left, and finally discharged into the exhaust chamber, as is being done in the right hand low-pressure cylinder. The point of cut-off is fixed, regulation being effected by a throttle governor operated in an obvious manner by the revolving weights upon the shaft at the right.

It will be seen that a compound or even triple-expansion engine may be run as a simple one by merely removing the upper pistons and the piston

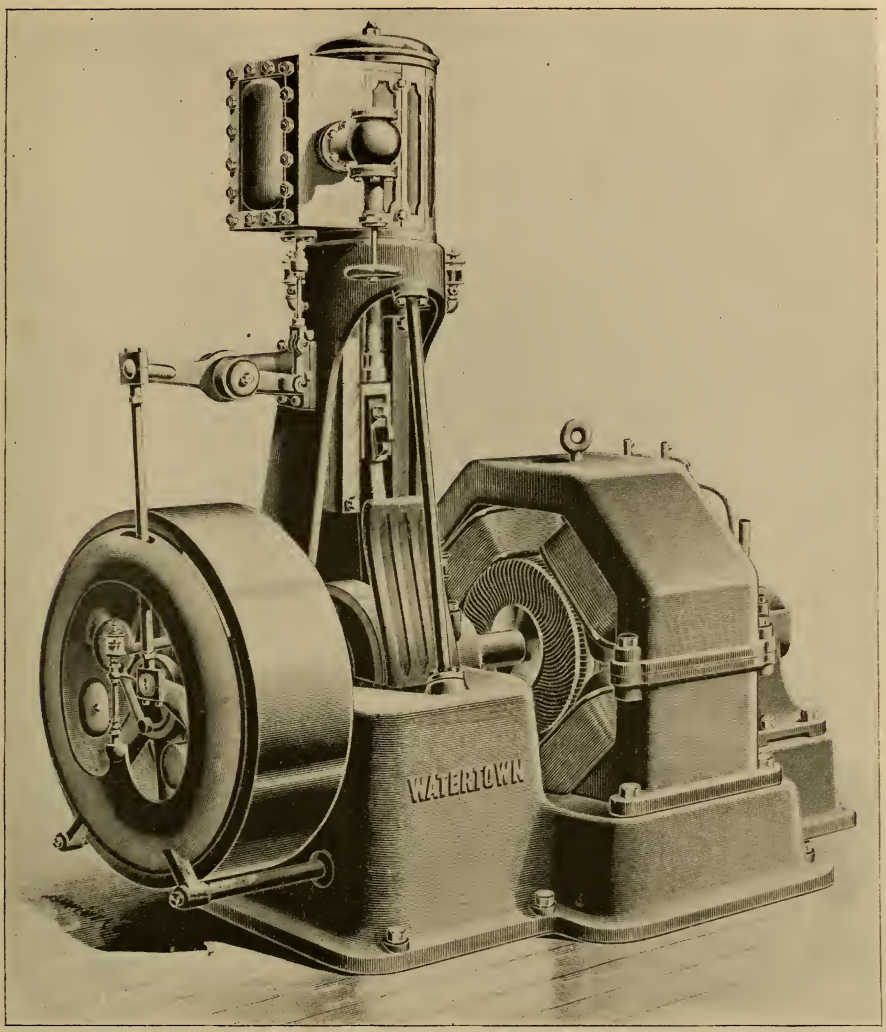
valves corresponding with them, and these might even be left were it not for the useless friction of the rings. The upper cylinders in such a case become mere extensions of the steam chest. The exhaust ports being in what is always the lowest plane of the working cylinder, the water of condensation or entertainment finds a natural and continuous escape during the period of exhaust opening. In the low-pressure cylinders of all engines, and in the high-pressure cylinders if large enough to be so treated, internal relief valves are fitted, consisting of a gun-metal plug screwed into the top of the low-pressure cylinder. The plug is pierced by holes, covered by a single thin gun-metal disk. When the disk is raised, there is free communication between the cylinder and the receiver, or steam chest, above it. It is kept down under ordinary circumstances by the excess of the receiver pressure over that in the cylinder; therefore no spring is required.

If, from water in the cylinder or any other cause, the pressure rises above that in the receiver, the valve lifts, and though the water is only passed back into the receiver, the relief is found to be sufficient, and, in fact, far more effective than that given by ordinary external relief valves.

In cases where internal relief valves cannot be used, ordinary external valves are fitted. When an engine is run without load, the compression in the low pressure cylinder may rise beyond the pressure in the receiver; the disk of the valve may then be heard to lift at each revolution, but the noise will stop as soon as the receiver pressure is increased by giving the engine work to do. Relief cocks are fitted upon the guide cylinders, in order to avoid compressing the air in them when the engine is being turned by hand, and to facilitate starting. If the cocks are opened at starting they must be closed again immediately. The lower portion of the engine is encased, the cranks



DIRECT-CONNECTED ENGINE, BUILT BY B. W. PAYNE & SONS, ELMIRA, N. Y.

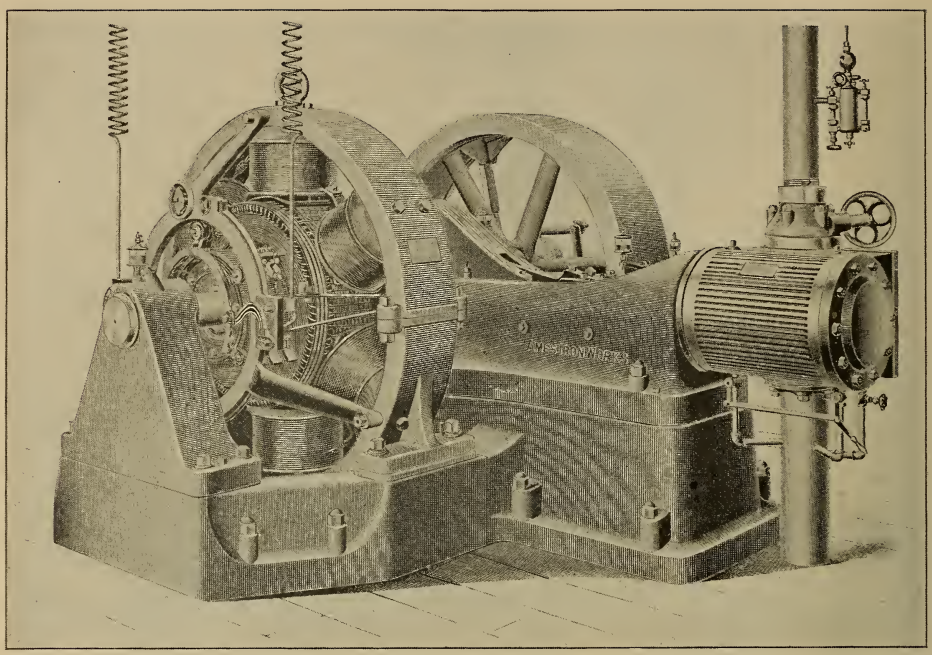



DIRECT-CONNECTED ENGINE, BUILT BY THE WATERTOWN STEAM ENGINE CO., WATERTOWN, N. Y.

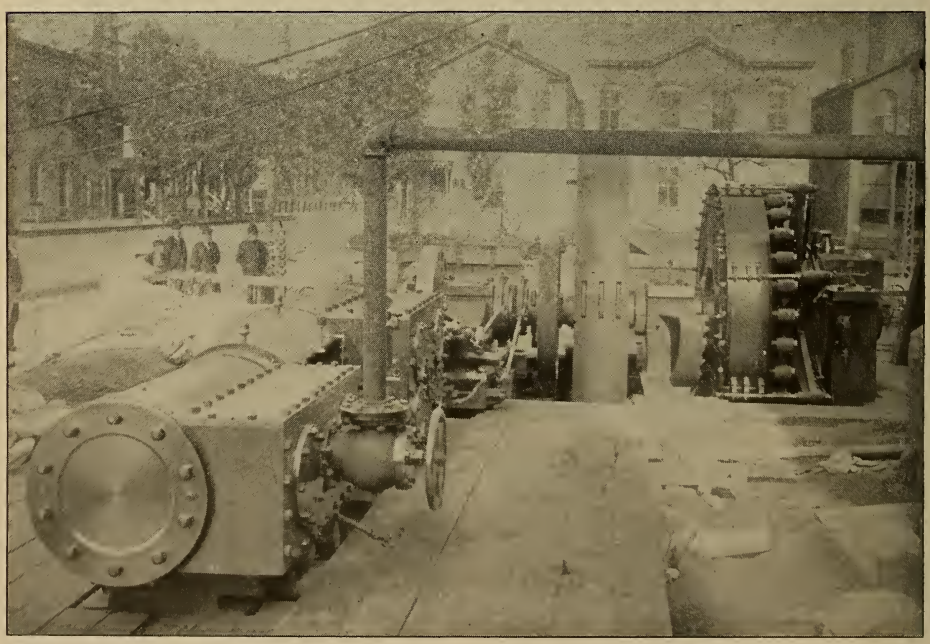
dipping into oil at each revolution. The standard sizes run as high as 360 horse-power, making 350 revolutions per minute.

Special prominence has been given to this engine because of its decidedly unconventional features, which have not yet become as widely known as they deserve. The engine itself, and not its combination alone with a dynamo, is something new, differing in this respect from the larger number of direct-connected outfits now available, in which, often, the engine is of a standard design which has been turned out for several years past, and the feature of chief interest is simply in the coupling together of engine and generator. Still, there are several other direct-connected types which have appeared quite recently in which the engine, too, as well as the combination, is new.

Among these is the vertical compound engine, brought out a month or two ago by the Ball Engine Company, of Erie, Pa. The aim at strength and rigidity

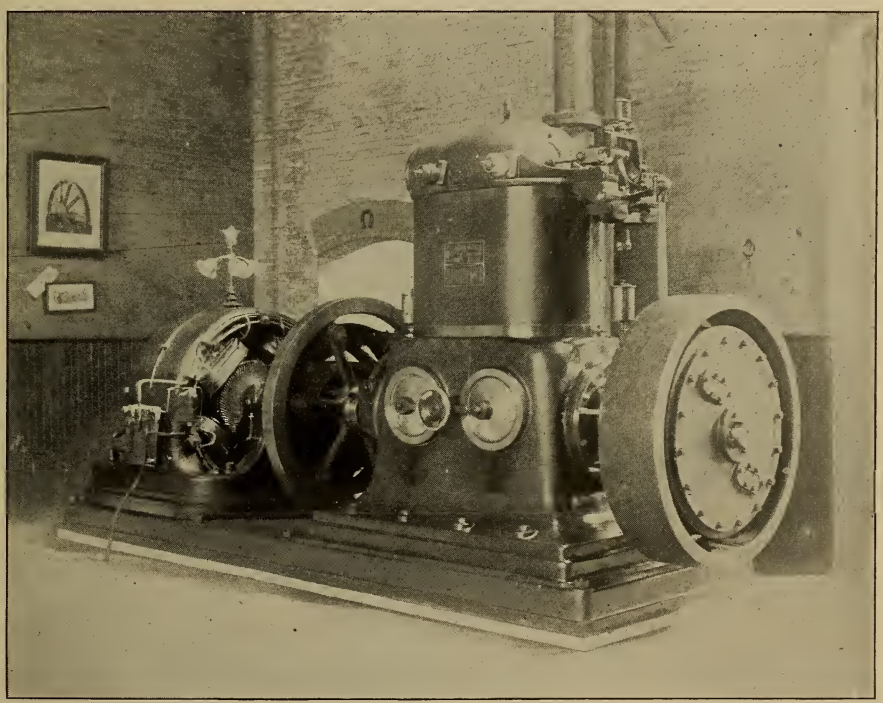


DIRECT-CONNECTED ENGINE AND GENERATOR, BUILT BY THE AMES IRON WORKS, OSWEGO, N. Y.



BUCKEYE ENGINE AND SIEMENS-HALSKE GENERATOR, BUILT BY THE BUCKEYE ENGINE CO., SALEM, OHIO

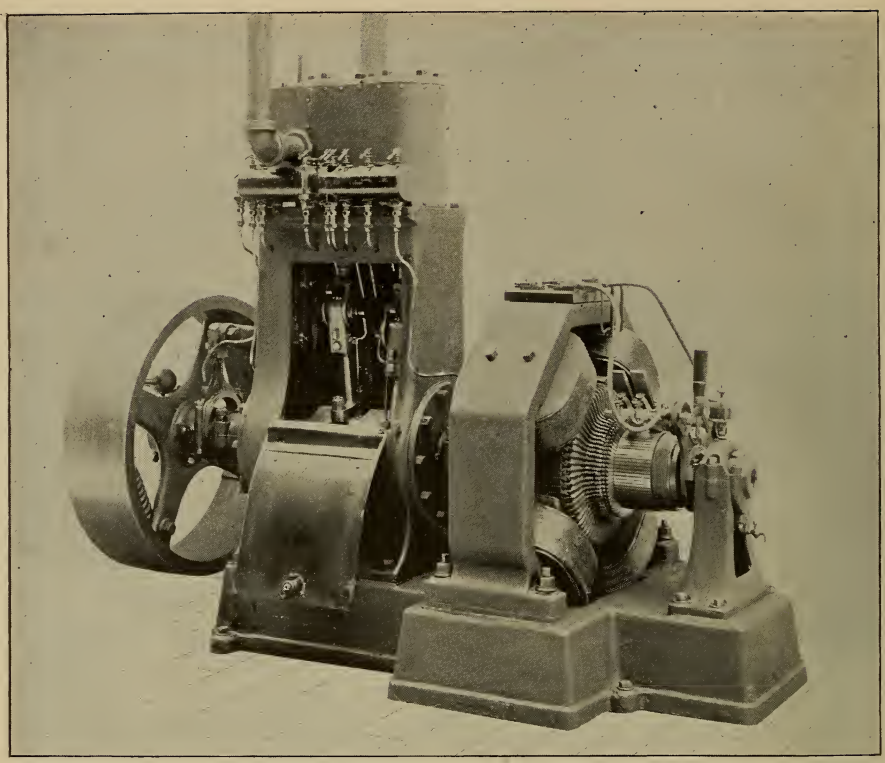
in this engine was fully attained in the symmetrical form of the upright housings which are made to constitute one double housing by having one side of each planed and bolted together in the centre of the middle shaft bearing. This substantiality is still further increased by planing the bottom of both housings to one continuous flat surface to meet the planed surface of the top of the single base plate to which the bottoms of the housings are bolted.



A KODAK OUTFIT, BUILT BY THE WESTINGHOUSE MACHINE CO., PITTSBURGH, PA.

The cylinders are provided with single valves, each of which is practically one piece so far as the motion and wear are concerned. The high pressure valve is of the double faced telescopic relief type, with boiler pressure on the inside and a sufficient amount of unbalance area on the faces, so that the pressure of the steam on the inside forces the two faces apart, causing each to rub against the seat sufficiently to keep the surfaces polished and steam tight. The low pressure valve is of the common D type, with improved proportions and construction, and is provided with a round relief area upon its back, operating against the chest cover, thus having a large, well proportioned valve that runs with the greatest ease and yet follows up its wear without attention from the outside. The engine shown on page 288 is employed in electric railroad work, and is developing from 425 to 435 horse-power at a speed of 235 revolutions per minute.

Another novel design is the vertical compound engine built by the Ball & Wood Company of New York, who, until quite recently, confined themselves to horizontal makes. The engine is shown on page 290, without a generator, as the latter was not in place, ready to be photographed. The most striking feature of the design is found in the valve gear. The admission of steam into each port is controlled by two concentric Corliss valves, the expansion valve being hollow, and fitting, like a



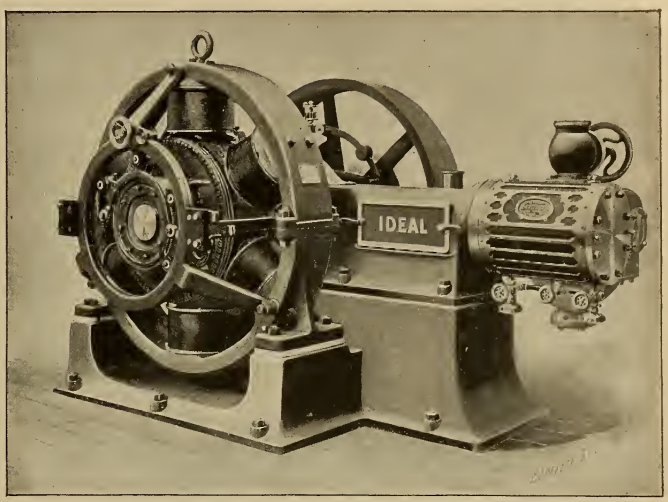
DOUBLE-CYLINDER DIRECT-CONNECTED ENGINE, BUILT BY THE B. F. STURTEVANT CO., BOSTON, MASS.

sleeve, over the cut-off valve, which is controlled by a wrist plate connected to a shaft governor. The expansion valves are driven by a second wrist plate in front of the cylinders, this also operating the exhaust valves of both cylinders.

The shaft governor is keyed to a horizontal shaft, a short vertical shaft and two pairs of bevel gears transmitting the power. The horizontal shaft, besides carrying the governor, supports a disk on the front end, and a rod connected to this disk drives the front wrist plate. The latter, instead of oscillating about a fixed pin, is keyed to a shaft which extends through to the rear of the engine, where it supports a rocker arm keyed to its rear end. The hub of the rocker arm is extended to receive the rear wrist plate, which controls the cut-off valves. The wrist plate turns about the hub, a brass bushing being introduced to prevent wear. The engine has 19 x 31 x 24-inch cylinders, will run at a speed of 150 revolutions per minute, and with 125 pounds initial pressure, is to develop 600 horse-power, running non-condensing. The generator to be coupled to it will be a 200 kilo-watt multipolar General Electric Company dynamo.

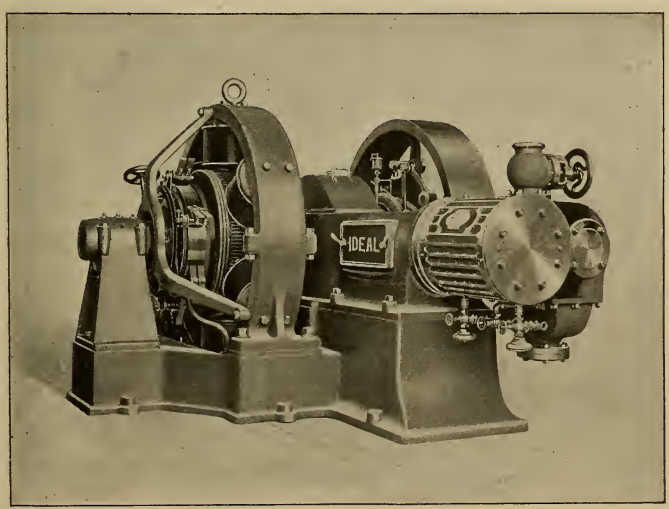
The Watertown Steam Engine Company, of Watertown, N. Y., also have made a departure from their standard line in the shape of the vertical high-speed engine shown on page 293. Engine, dynamo and all bearings are mounted on one base, holding all these parts in perfect alignment. The vertical rod supporting the cylinder in front can be slipped out in a very short time, enabling the shaft, armature and governor to be easily taken from the engine should it become necessary. The governor is exceedingly simple, and regulation is claimed for the engine within a very small fraction of one per

cent. between the limits of full load and no load. Surrounding the governor is an oil shield which receives all the drippings ordinarily allowed to collect in the rim of the wheel. The waste oil is carried to the base of the oil guard, where it may be drawn off at any time while the engine is running. The shield may be attached to the subbase, as shown in the illustration, or supported by a separate foundation. The valve details are substantially the same as those of the standard Watertown engine.




AN IDEAL DIRECT-CONNECTED ENGINE, BUILT BY A. L. IDE & SON, SPRINGFIELD, ILL.

B. W. Payne & Sons, of Elmira, N. Y., are putting on the market a 10½ x 12-inch centre-crank engine, connected to a 25 kilo-watt General Electric Company multipolar generator. The field magnet support and engine proper are all fixed to one base plate of sufficient weight to give rigidity to the whole outfit. The general features of the engine are of the well-known Payne type.



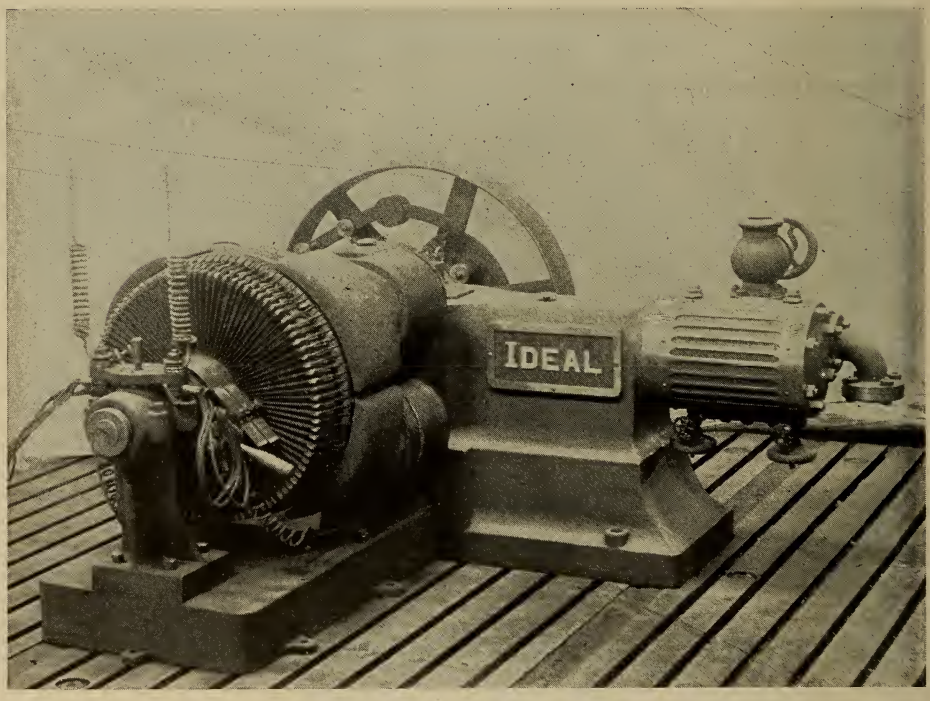

AN IDEAL DIRECT-CONNECTED ENGINE BUILT BY THE HARRISBURG FOUNDRY AND MACHINE WORKS, HARRISBURG, PA.

A direct-connected Ames engine, built by the Ames Iron Works, of Oswego, N. Y., is shown on page 294. This has a 13 x 12-inch cylinder, runs at 275 revolutions per minute, and is coupled to a 50 kilo-watt multipolar generator. The entire floor space occupied by the plant measures only 7 feet 6 inches by 9 feet 4 inches. The engine is of the single-valve, automatic kind, the valve being simply a flat, rectangular casting, finished on both sides, and working between the seat and a heavy pressure plate. The Buckeye tandem-compound, direct-connected engine shown on page 294, was recently

armature, which is keyed on the extended engine shaft, is supported by an out-board bearing, but this and the

erected in one of the power houses of the Cincinnati Consolidated Street Railway Company, of Cincinnati, Ohio. The engine has a 20-inch high-pressure and a 32½-inch low-pressure cylinder, and a 36-inch stroke. The dynamo to which it is coupled is a 500 kilo-watt Siemens–Halske railway generator. The engine is running non-condensing, making 114 revolutions per minute.

One of the Westinghouse "Kodak" coupling between the engine and dynamo is so designed that it is equivalent to the flexibility of a belt in case of sudden shocks and overloads due to short circuits on railroad lines or from other causes. Besides this, the coupling permits of end play in the dynamo shaft, and permits of the engine and dynamo shafts being considerably out of alignment, which may be caused by settling of foundations, unequal wear of bear-

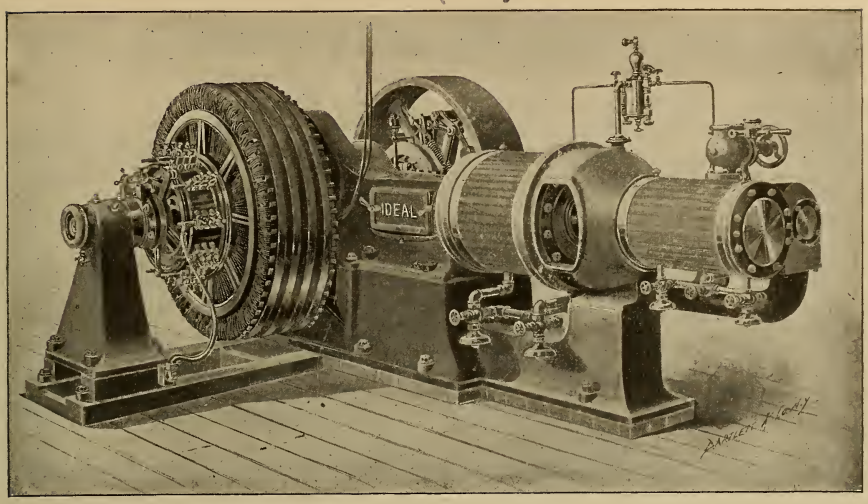



AN IDEAL ENGINE WITH SPERRY ARMATURE, RUNNING AT 550 REVOLUTIONS.

outfits, as they have been termed, consisting in this instance of a compound engine and a 100 horse-power railway generator, is shown on page 295. These Kodak rigs are in all cases direct connected by means of flexible spring couplings, the generator and the engine both being on the same cast-iron bed plate. The generator is the regular multipolar railway generator, as built by the Westinghouse Electric and Manufacturing Company, and the engines are the regular Westinghouse compound automatic. The spring

ings or carelessness on the part of anyone erecting the outfits. The coupling has been operated satisfactorily in cases where the shafts were not only out of alignment, but where one shaft was nearly an inch higher than the other. The Kodak outfits are at present built in sizes from 5 horse-power to 1000 horse-power, the smaller sizes being furnished with the standard Westinghouse engine.

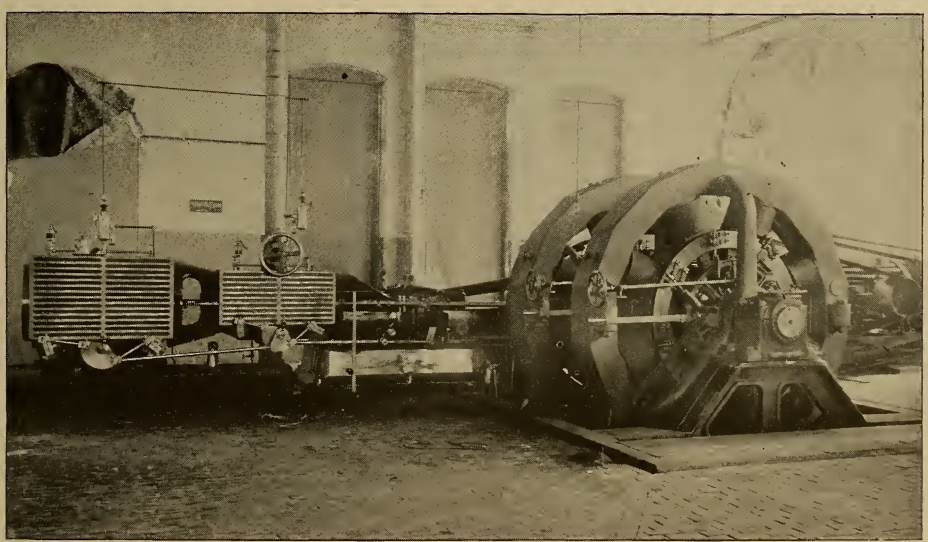
The engraving onpage 289, of the direct-connected Woodbury engine, built by the Stearns Manufacturing Company,




TANDEM COMPOUND ENGINE, BUILT BY THE HARRISBURG FOUNDRY AND MACHINE WORKS, HARRISBURG, PA.

practically explains itself. The engine is one of the many well-known single-valve automatics which have been brought out in the United States within the past half-dozen years, and has met with a goodly share of favor.

In the combination shown on page 296, turned out by the B. F. Sturtevant Company, of Jamaica Plain Station, Boston, Mass., the engine is a single-valve, double-cylinder vertical design, the two cylinders being placed side by side in the same casting. The cranks are set opposite each other, that is, at an angle of 180 degrees, and steam is admitted simultaneously to the top of one cylinder and the bottom of the other. The reciprocating parts are accurately balanced. The cylinders are of large diameter as compared with



FOUR-VALVE COMPOUND DIRECT-CONNECTED ENGINE, BUILT BY RUSSELL & CO., MASSILLON, O.

the stroke, so that a relatively great power is developed at high rotative, but moderate piston speed. Admission of steam to both cylinders is regulated by a single piston valve, under the control of a shaft governor of special design, and automatic relief valves are provided to prevent any danger of damage by water in the cylinder. Complete sight feed oiling arrangements connect with all of the bearings and the frame entirely encloses all running parts at the same time, leaving them perfectly accessible by the mere opening of the door. This feature is of special importance and renders the engine, like others similarly arranged, of great service in many locations where the dust and grit present in the atmosphere would rapidly destroy the bearings of an ordinary engine.

One of the interesting exhibits at the World's Fair at Chicago last year was a small, 6 by 6-inch Ideal engine having a 150-light Sperry armature wound on its shaft. It was built in 1888 and was originally put to work lighting part of the establishment of the builders, Messrs. A. L. Ide & Son, of Springfield, Ill. The engine ran noiselessly at 550 revolutions per minute and gave remarkably good services. As shown at Chicago, the working parts were exactly as they were while in use in the shop. But it is not to small, direct-connected work alone that the Ideal engine has been applied. A great many of comparatively large size have been turned out for direct driving during the past few years and have been working with highly satisfactory results.

For the eastern part of the United States the Ide and Ideal engines are built by the Harrisburg Foundry and Machine Works, of Harrisburg, Pa., two of their designs being shown on pages 297 and 299. The tandem-compound outfit has 17 x 28 x 18-inch cylinders, runs at 180 revolutions per minute and is rated at 300 horse-power. On account of the load being driven from one side from a 30″ belt, an out-board bearing is provided on the belt side, allowing the crank shaft to extend beyond the bearing to take the overhang, and relieve the main bearings. This has proved very satisfactory in a number of electric railway plants so equipped.

The valves on both the high and the low pressure cylinders are adjustable piston valves designed by Mr. M. E. Hershey, the general manager of the Harrisburg Company, the high pressure valve being controlled by the governor, while the low pressure valve is worked by an eccentric on the opposite side, with direct connections.

The compound engine, shown on page 299, is one of the four-valve designs of Russell & Co., of Massillon, O., the admission and cut-off valves being multi-ported balanced slide valves, while the exhaust valves are cylindrical and are operated through wrist plates by the same eccentric that works the main steam valves. Both high and low pressure cylinders are controlled by the governor. The particular engine here shown is a 15 x 24 x 24-inch, capable of developing from 300 to 400 horse-power, and is coupled to two of the General Electric Company's generators, the plant having been installed for the Edison Electric Light Company, at Grand Rapids, Mich. The bed of the engine and the fields of the dynamos rest on a common iron base, while out-board pillow-blocks, in detachable stands, are provided for the armature end of the shaft.

With these examples of recent direct-connected practice the list of available designs is, however, by no means exhausted. The selection has been made at random from a large number of outfits, simply with the view of illustrating the present tendencies of builders and users. Other designs equally good and equally interesting are now on the market—too many, in fact, to admit of all being shown here.

# PRESERVATION OF WOOD.

*By O. Chanute, C. E.*

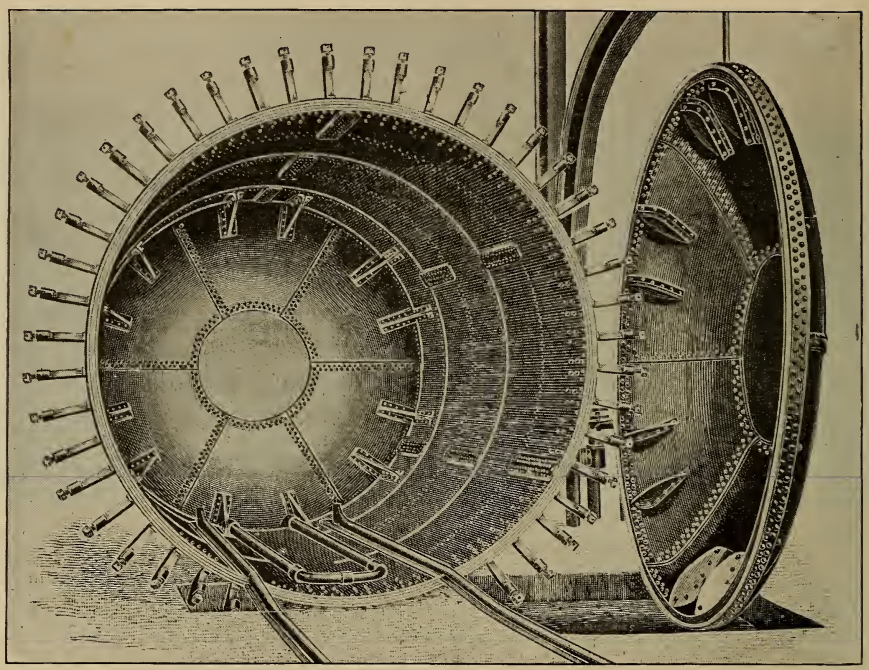
WITH the opening of the railway era and the consequent great demand for timber, renewed attention was turned to chemical methods for retarding the decay of wood, the more so as England, France and Germany, which were so copiously wooded at the beginning of the Christian era, had been pretty well denuded by the year 1830.

Many wood-preserving experiments had previously been tried, chiefly for the preservation of ships' timbers, so that in a treatise on "The Preservation of Timber," by Wm. Chapman, C. E., published in London in 1817, the author gives, after noticing the writings of his predecessors, the records of their and his own experiments, made principally upon perishable woods or beef flesh, with the following substances :—

Corrosive sublimate.
Sulphate of copper.
Sulphate of zinc.
Coal-tar oil
Sulphate of iron.
Nitrate of silver.
Carbonate of soda.
Caustic soda.
Arsenic.
Common salt
Quick lime.
Barytes.
Copper and iron sulphates.
Soap.
Resin.
Vegetable oils.
Fish oils.
Essential oils.
Vapors of oils.
Charring.
Charcoal powder.
Mineral coal.
Alumine.
Selenite.

It is thus seen that modern chemistry suggested, at an early day, almost all the substances likely to prove of value as antiseptics. In 1832, Kyan patented the use of corrosive sublimate, and his process became known as "Kyanizing." In 1837 Margary patented the use of sulphate of copper. In 1838 and 1848 Bethel patented the application of coal-tar oil, or creosote, since known as "creosoting," and in 1838 and 1840 Burnett took out patents for the application of chloride of zinc, which process was termed "Burnettizing." Many inventors followed with patents for all sorts of methods and substances, but the first mentioned four antiseptics may be said to be the only ones which have proved of real value after these many years of experience, and of these only creosote and chloride of zinc are now extensively used.

At the beginning, wood preservation proved a tempting field for speculative experiments, and as it takes from 7 to 10 years to ascertain the real value of any treatment, many processes, once well thought of, have proved failures in the end, so that, of late years, only few



A CREOSOTING CYLINDER IN USE ON THE LONDON AND NORTHWESTERN RAILWAY, ENGLAND.

new proposals have been brought forward, and not many of these have proved to be of value. These have been chiefly modifications in the mode of injection.

The methods of application originally employed were the following :—1st. Steeping the wood for several days in the chemical solution selected; 2d. Vital suction of chemicals by the growing tree ; 3d. Forcing solutions through freshly cut logs by hydraulic pressure, in the open air ; and 4th. Forcing solutions by hydraulic pressure applied in a closed vessel containing the wood.

The first method is still employed in kyanizing ; the second and third have been abandoned, and the fourth has been gradually modified and improved, until it is now almost universally used. In applying this, the wood to be treated is first loaded upon small cars, and these are run into an iron cylindrical vessel, generally from 40 to 110 feet long, 5 or 6 feet in diameter, and of appropriate strength. Then the door is hermetically closed and the vessel is filled with steam at a pressure sufficiently low (from 18 to 20 pounds to the square inch) not to injure the strength of the timber. This steaming is intended to liquefy the sap and to warm up the wood, especially the air contained in the sap cells, and is continued from half an hour to three hours, in accordance with the condition of the wood or the subsequent treatment which it is to receive. Then the steam is let out and an air pump is set at work to produce a partial vacuum (about half an atmosphere) in the vessel. The result of this is that the heated air in the sap cells expands and drives out a portion of the sap, which latter is pumped out and run to waste. The wood being thus prepared to receive the solution, this is run in and hydraulic pressure applied by means of pumps. The effect of this is to force the chemicals into the sap cells of the wood, chiefly, it is believed, through the ends, and to compress whatever air may remain therein, so as

to cause greater absorption. The pressure varies, at different works, from 60 to 150 pounds to the square inch, and is maintained for from one to four hours. In some processes, as will be explained further on, several successive solutions are used. When the wood has been sufficiently impregnated, the solution is driven back into its storage tank, generally by pumping compressed air into the top of the closed vessel; the latter is then opened, the wood is withdrawn and the whole operation is then repeated. The total time occupied varies from three to twelve hours at the numerous works which employ this pressure process.

Creosoting has been found to be the best of all the preservatives. It is the only one effective—when well done—against the sea worms (Teredo Navalis and Limnoria Terebrans) which feed on timber, but it is also the most expensive. The general practice is to inject from 8 or 10 pounds to the cubic foot in timber to be subsequently exposed merely to the weather, and from 10 to 20 pounds to the cubic foot in timber to be exposed to sea worms. The quantity used varies with the activity of the worms, those dwelling in Southern waters being apparently more voracious than those in Northerly ports, and feeding on the wood all the year round instead of hybernating. As creosote costs, generally, about one cent a pound in the United States, the total cost of creosoting, when well done, may be estimated at from twelve to sixteen cents a cubic foot (from thirty-six to forty-eight cents per tie of 3 cubic feet) for timber to be exposed to the weather, or at from fourteen to twenty-four cents a cubic foot (from $12 to $20 per 1000 feet board measure) for timber to be exposed to marine worms. Prices are somewhat cheaper in Europe in consequence of cheaper creosote, and this process is exclusively used in England, where the numerous gas works afford cheap coal tar.

As it has been found injurious to cut into the wood after treatment, thus removing the outer protection, which is the most effective, timber is generally framed before creosoting. An interesting application of this is shown in the illustration opposite, which represents a creosoting cylinder, 12 ft. 6 in. internal diameter by 22 ft. long, recently constructed by the London and Northwestern railway and installed at Earleston, for the purpose of creosoting bodily its coal and cattle freight cars after they are put together.

Creosote is distilled from coal tar and contains a number of tar acids (carbolic, cresylic, acridine, etc.), which are powerful antiseptics, in solution with a thick, gummy, insoluble oil containing naphthaline. It thus acts chemically by poisoning the germs of decay, and mechanically, by repelling the intrusion of moisture. The amount absorbed and the consequent benefits conferred vary with the character and density of the wood, but it may be said, in general terms, that timber and railroad ties, properly creosoted, will last from 8 to 20 years, and that creosoted piles, exposed to sea worms, will last from 10 to 20 years, if the work be well done and the creosote be of good quality. The temptation to do poor work or to buy cheap creosote is, however, very great, for the material is expensive. In the early days, all sorts of patented processes were introduced to diminish the quantity used, such as injecting the timber with cold creosote instead of hot, which is more limpid, limiting the pressure and time of treatment, treating with vapors instead of oil, etc., but these have all given bad results and are abandoned.

The mode of application in burnettizing is much the same as in creosoting, except that the solution is more frequently admitted at atmospheric temperature, instead of being heated. The chloride of zinc is obtained by pouring hydro-chloric acid upon metallic zinc in a lead-lined vat, thus forming zinc chloride. The process may be hastened by steaming, and the resulting solution is about 50 per cent. strong. Care must be taken to obtain a saturated solution, as free acid injures the strength of the wood, even when reduced to the

1.50 to 3 per cent. solution which is injected.

Various species of wood differ greatly in their receptive qualities, some absorbing 50 per cent. more solution than others. It is, therefore, advisable to select for treatment the more open-grained, porous woods, provided they have sufficient hardness to withstand the intended wear. It may be said, in general terms, that black and red oak, mountain pine, hemlock and beech receive burnettizing well and are greatly benefited by it. White and burr oak, chestnut, yellow pine or spruce are too close-grained and should not be treated; they are durable woods generally and but little sap can be extracted from them. A transverse section of hemlock wood, greatly magnified, is shown in the illustration on the page opposite.

Great care has to be exercised in regulating the strength of the solution injected. If it be too strong the wood will be made brittle, and if it be made too weak the zinc will wash out in time and leave the timber unprotected. In Germany, where burnettizing is all but universally used for railroad ties, the best results are said to have been obtained with solutions 1.90 per cent. strong, while in the United States solutions 3 75 and 5 per cent. strong rendered the ties "as brittle as carrots." The aim should be to have the wood contain at least one-quarter of one per cent. of zinc chloride of its own weight when dry. For this purpose it is advisable to vary the strength of the solution from time to time, in accordance with the condition of the wood, for, when freshly cut, it takes in far less of the liquid than when dry. How much it will absorb when in the latter condition may be realized from the fact that 31,006 mountain pine ties, treated in August, drank up 1,679,289 pounds of solution, an average of 54 pounds per tie, or 9 tons per average cylinder-full of 333 ties. The zinc absorption was, in that case, 0.65 of one per cent. of the weight of the wood, although the solution was only 1.46 per cent. strong.

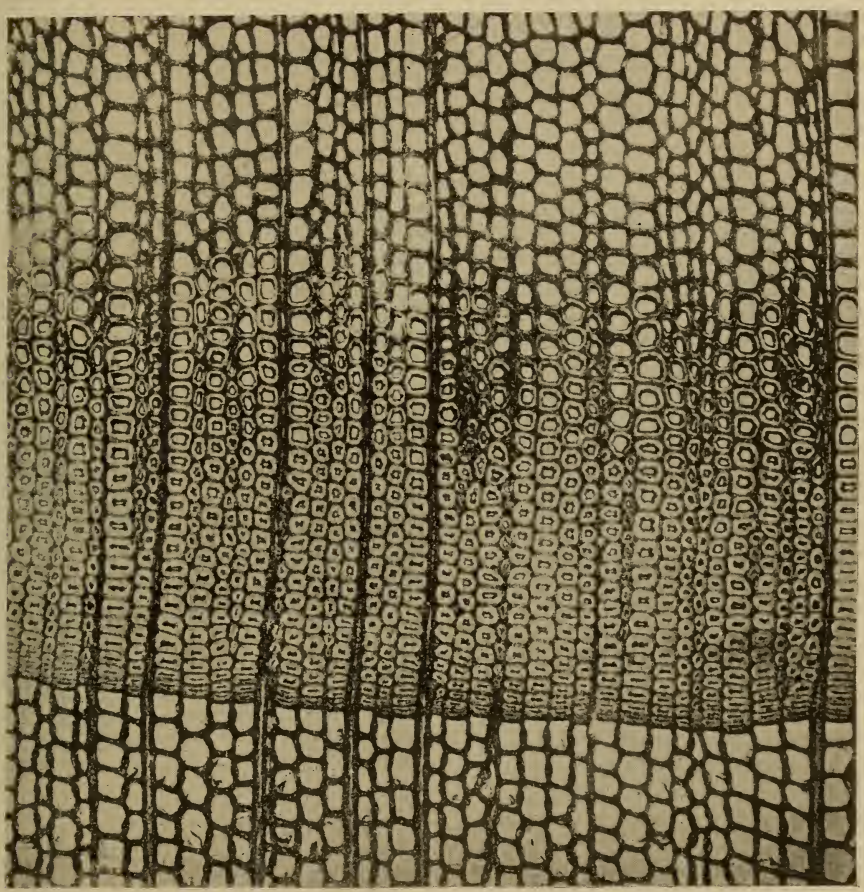
For bridge work burnettizing has been found to render the timber unduly brittle, particularly for those pieces exposed to tensile or to cross strains, but for railroad ties it has given results, under favorable circumstances, but little inferior to creosoting. It lengthens the life of various species of wood, which would otherwise decay in the track in from 3 to 5 years, to a life of from 8 to 18 years, varying somewhat with the exposure and with the individual ties. This results probably from the difference in density of individual trees, as determined by their exposure and soil, for, upon weighing a lot, simultaneously cut from the same forest, and seasoned in the same way, just before and just after treatment, the differences in absorption were found to range from 13 per cent. to 80 per cent. of the weight of the ties. The result is that preserved ties, like those in their natural state, do not all give out at once, but that some show a longer life than others. The principal difficulty with burnettizing is that the zinc, being a very soluble salt, is apt to wash out of the wood when placed in a wet exposure. A number of devices have been resorted to for the purpose of preventing this.

In the United States a process has been introduced in which two solutions are used. The first consists of zinc chloride, to which a little gelatin has been added, and when the wood has been impregnated with this, a second solution of tannin is introduced and forced into the wood. The gelatin and the tannin, coming into contact, form insoluble pellicles of artificial leather, which act as diaphragms and so prevent the zinc from being washed out. Several millions of ties have been prepared by this process within the last nine years, and it seems to be giving satisfactory results.

In Germany, reasoning from the fact that the effectiveness of creosote results from the combination of antiseptics with an insoluble oil which repels moisture, a process has been introduced in which an aqueous solution of chloride of zinc is mixed with about 8 per cent of creosote. As water and oil will not dissolve each other, the result is not a solution, but an emulsion, and mechanical means

have to be adopted to keep the two intimately mixed. The process is said to be a success, but if a true chemical solution could be obtained of some of the metallic antiseptics with a cheap oil, such as petroleum, it is probable that still better results would be obtained. Efforts have been made by chemists to compass such a solution, but thus far the boilers." It is said that "under this combined treatment the wood is impregnated in one hour, instead of in the 10 to 40 hours which would be required by the solution alone, unaided by the electric current." The beneficial results of this are yet to be ascertained.

The cost of burnettizing varies from four and one-half to seven cents per



A MAGNIFIED SECTION OF HEMLOCK.

without success. In France experiments are being made with the aid of electricity. "The wood is exposed to the simultaneous action of the saline solution heated by a steam jet, and to a current of electricity produced by a dynamo, the poles of which are connected to electrodes fixed to the ends of

cubic foot, say from fourteen to twenty cents per tie, in accordance with the process adopted, the kind of wood selected and local circumstances. It is thus seen to cost less than half as much as creosoting, and to give results but little inferior, except in the case of timber exposed to sea worms, where

creosoting alone has proved a specific.

As already intimated, corrosive sublimate and sulphate of copper are now but little used. There are still in Europe and in the United States a few establishments working with these antiseptics or with some processes which are on their trial, but they are not numerous and are not increasing in number. For work to be done upon a large scale, the choice lies, practically, between creosoting and burnettizing, including therein the various modifications in the mode of application of these preservatives. The principal scope for the preservation of wood lies in its application to railroad ties. For this it has proved thoroughly effective, and there is no longer any question of its economy in Europe, so that railway managers there who fail to avail themselves of it, are alluded to as neglecting an important economy. In the United States there are as yet few railroads which resort to such treatment. This results from the comparative prices of the untreated ties. In Europe they cost from sixty cents to one dollar each, while in the United States the first cost is from twenty-five to seventy-five cents each, in consequence of the present abundance of timber. There are many roads, however, upon whose lines the more durable woods have been so far exhausted that the inferior woods can be procured and treated at a less aggregate cost than the white oak, burr oak and chestnut which have thus far constituted the tie supply. The necessity for doing this has, for a time, been retarded by opening up new sources of supply in the extension of other railroads, or the shipping of ties from forests contiguous to navigation; but it is very evident that even these supplies will be exhausted after a time, and that there will be an increasing number of railroads which will find an economy in resorting to wood preservation.

Such roads should first endeavor to have the inferior, cheap and perishable woods treated, both because they have been found to absorb antiseptics best, and because they will be cheaper. When white oak ties cost fifty-three cents each, and hemlock 30 cents each, unprepared, the latter, if burnettized, will procure an economy of about $100 a year per mile of track maintained. There were, at an early day, numerous failures with even the best processes, but these have gradually been traced to their causes, and there is now no question as to the results which can be accomplished. It is necessary, however, that the treatment should be well and skillfully done, for there are many idiosyncrasies in the various species of wood which require experience to get the best results. Allusion has already been made to the fact that it is not indifferent as to what species is selected for treatment; to the care which should be taken to ascertain the condition of the wood, so as to vary the strength of chemical solutions or the length of the treatment accordingly; and to the differences which exist in the receptivity of individual trees. To this it may be added that most woods should be allowed to season, if at all practicable, before treatment, but that in some species the resulting evaporation of the moisture from the sap, leaves the latter hard and gummy, thus resisting absorption; and that it is very desirable to allow the treated ties to dry out as much as possible before laying them in the track, so as to remove the watery portions of the solution; also that if decay has already begun, the wood should not be treated at all. It will then absorb the solution copiously, but the decay will proceed much more rapidly than it does in sound, treated ties.

Much depends also upon the time at which the wood is cut. In northern latitudes it is best to cut in the winter, and this is now the general practice, while in southern latitudes it is said that it is best if cut in the autumn, the reason in both cases being the same, that the period should be selected in which, either from the cold in the North or the dryness of summer in the South, there is the least quantity of perishable sap in the wood. Those curious on the subject will find many data and records of experiments in a report made by a

committee on the preservation of timber, to the American Society of Civil Engineers, and published, together with the discussions on it, in the transactions of that society for July, August and September, 1885. This sets forth, at considerable length, the results of American experience, as well as the conditions of success, and has since been reinforced by a number of interesting bulletins from the Forestry division of the United States Department of Agriculture, calling attention to the relation of railroads to the forest supplies, and inculcating various methods of promoting economy.

The time has not yet arrived when any economy will accrue from the use of metallic ties in the United States. If made of adequate strength the annual interest on the outlay will amount to more than the annual renewal of wooden ties, particularly if the latter are chemically preserved.

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# SOMETHING ABOUT FIRE ENGINES.

*By Joseph Sachs.*

PROBABLY no other natural force or element has caused more destruction than fire. Although various extinguishing agents are, and have been, used, water always has been and will continue for some time, to be the principal, simplest and most easily applicable cure for a conflagration of any magnitude. To speedily and efficiently apply this fire-killing fluid has been the great aim, and the methods of doing so have gradually been developed from the crudest and most primitive appliances to the perfected systems of to-day.

Among the earliest apparatus for applying water to fires was a large squirt, or syringe, consisting of a tube, filled with water from a tub, which was rapidly ejected by means of a plunger operated by hand. This, in various forms, continued in use for a long time. What is, perhaps, the oldest known fire engine for pumping water, is mentioned in the Spiritalia of Hero, about 150 B. C. From the description there given this engine had two single-acting pumps, the plungers of which were worked by a single beam, pivoted between the two. The streams united in a single discharge pipe, passing up a trunk in which was an air chamber, and out at a nozzle which could be turned in any direction. This description might stand for a great many forms of hand fire engines used even to the present day. The early Romans appear to have paid quite some attention to fire extinguishing apparatus, and had an organized fire brigade.

Something like the more modern fire engine appears to have been brought out in the early part of the sixteenth century, and is described as a "water syringe." This was mounted on wheels and was worked by levers. Fire engines of this kind were apparently much used in Germany. In England, during the latter part of the sixteenth century, large brass syringes were employed, holding several quarts of water, and operated by three men, two holding the syringe at each side with one hand and directing the nozzle with the other, and the third operating the plunger. After having discharged the water, the syringe was refilled from a cistern or well near the fire, or from buckets. Later, these

A MODERN STEAM FIRE ENGINE.

water squirts were fitted to portable cisterns or tanks.

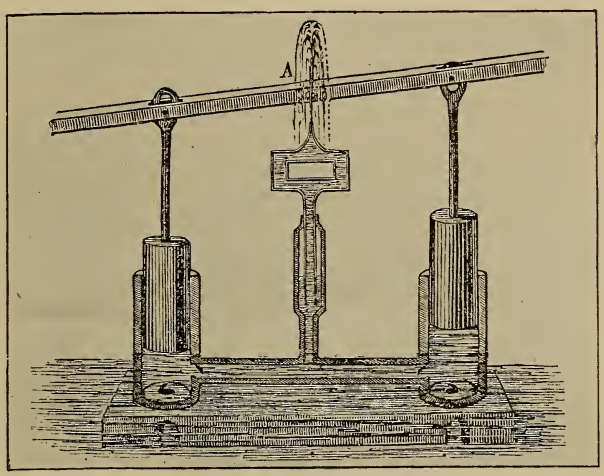
In the latter part of the seventeenth century a portable fire engine, with a double cylinder pump, mounted on a cistern or tank, from which water was drawn, was introduced in England by Newsham. This engine was, in many respects, similar to the modern hand fire engine, and continued in use in England up to 1832. The improved Newsham engine was operated by side rods, and for the portable cistern a suction pipe was eventually substituted. Single cylinder portable fire pumps were also used in France and Germany about this time.

The Newsham engine was, perhaps, the first successful fire engine, and really was the pioneer of the modern, manually operated engine. The pumps were of various sizes and designs, and were, in most cases, operated by levers. Various forms of engines, similar to the Newsham engine, continued in use as late as 1850. Even to-day hand engines are employed to quite some extent in the smaller towns and villages.

Stationary steam fire pumps were in use long before the portable steam fire engine made its appearance. About 1830, the firm of Braithwaithe & Ericsson, of London, brought out a steam fire engine of about six horse-power, capable of throwing 150 gallons of water per minute to a distance of eighty or ninety feet. It was drawn by horses. A similar engine of larger capacity was built in New York by Captain Ericsson in 1843. The first steam fire engine operated in the United States, however, was built by Mr. P. R. Hodge, at New York. This engine was self-propelling and the boiler, engine and pumps were placed horizontally. When it was necessary to operate the pumps, the driving wheels were raised clear of the ground, as the same engine was used for driving and pumping. The difficulty with all these early steam operated engines was their great weight and slow steaming ability.

A favorite type of modern steam fire engine consists of a quick-steaming, upright, tubular boiler, mounted at the

rear of a strong iron-frame truck, of which the goose neck type has been found the best. The pumps are generally of the double-acting, direct-connected design, and in most cases are fastened to the forward side of the boiler and placed vertically, with the steam cylinder uppermost. In one or two American steam fire engines, rotary pumps have been used with good results. The pumps of these different engines deliver into an air chamber to which the discharge hose is connected. Arrangements are also made to heat and pump the feed water, and in most engines the moving machinery is mounted upon springs.

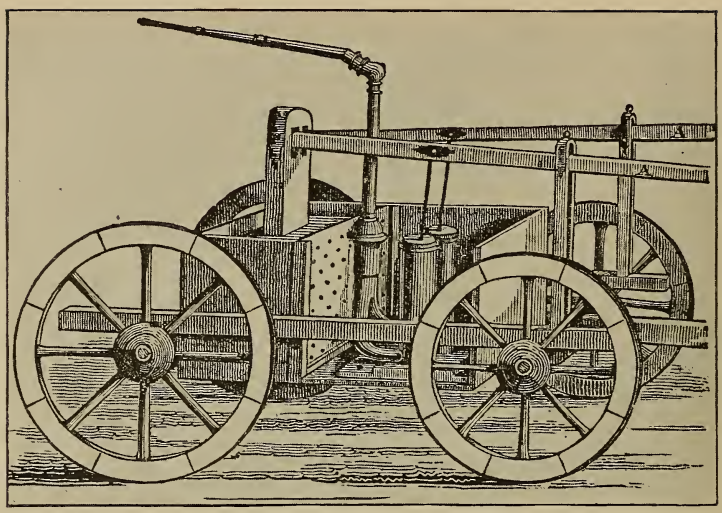



THE OLDEST KNOWN FIRE ENGINE.

FROM HERO'S SPIRITALIA.

Some years ago, when the steam fire engine was first introduced, forced draft was used to expedite raising steam while the engine was going to a fire. This was later supplanted by gas burners located in the furnace, which were continuously burning while the engine was at the engine house, thus keeping the water in the boiler at a fair heat so that steam could be quickly raised after the fire had been started and while the engine was on its way to the scene of action. Both of these plans have been done away with in most well-regulated fire departments. A stationary steam boiler at the engine house is now generally connected with the boiler of the fire engine, and keeps the water in this hot, so that steam, sufficient for pumping, can be raised in from three to ten minutes after the fires are lighted and while the engine is running to the fire. All the engines are supplied with the necessary flexible suction pipe to connect the pumps to the water plugs, but the discharge hose is, in most cases, carried by a separate tender or hose carriage. The larger engines have a capacity of from 800 to 1000 gallons of water per minute, discharging through from two to four outlets, the discharge hose generally being fitted with one and one-half to one and three-quarter-inch nozzles. Some extra large engines have a capacity even beyond this. The weight of these engines varies from 6500 to 7500 pounds, and they are generally from 22 to 25 feet long, from 8 to 9½ feet high, and about 6 feet wide. The piston speed varies from 200 feet to 300 feet per minute. The boilers have a large heating surface, and generally carry about 125 pounds pressure.

The modern steam fire engine is not a very efficient machine, and it is safe to say that from three to four times as



A STRASSBURG FIRE ENGINE OF 1739.

much coal is burned under the boiler per indicated horse-power than would be consumed by a good, every-day, stationary steam plant of similar capacity, say from 50 to 100 horse-power. However, the steam fire engine is built for speed and rapid duty, and not for economy.

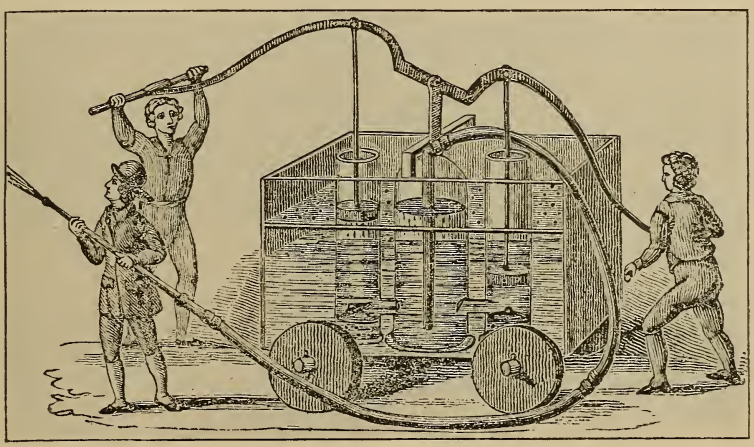
Stationary electric fire pumps are not new, and many establishments are to-day equipped with electrically-driven pumps that are used for this purpose. The suggestion of an electrically-operated portable fire engine is also not a new one. In fact, such engines have been built, and tried in several instances. As the present form of steam fire engine is self-contained, it would naturally appear that the electric engine should also be so. This, however, would not be absolutely necessary unless it were intended to make the engine self-propelling, as power could be furnished to the electrical engine in other ways. Although the self-contained electric engine is, perhaps, impractical and impossible, considered from an operative standpoint, an American patent was issued some time ago for such an engine. This consisted of a truck, mounted on wheels and carrying an electric motor connected to a rotary pump. The current was furnished by a large storage battery, supported 'in the rear of the truck. The

AN ENGLISH FIRE SQUIRT OF 1568.

engine could either be drawn by horses or propel itself by using the current from the storage battery. The motor could be used for pumping or for propelling the outfit, and was controlled from the seat on the truck.

Until the appearance, however, of an improved storage battery, lighter and stronger and more efficient than any known form of to-day, the practical electric fire engine can not be made self-contained, and therefore not self-propelling, but would be dependent for its supply of power on some central generating station from which the electric current could be distributed to various sections and districts by means of suitable underground or overhead wires, similar to those in use for electric light and power purposes. These wires would be supplied with various outlets at intervals in their respective districts, so that it would be possible to supply current to the motor of the engine by connection with these outlets. All such engines would be hauled by horses and would consist simply of a truck upon which an electric motor and some form of pump, preferably of the rotary type, would be mounted.

An electric fire engine, built and experimented with in England by Messrs. Siemens Bros. & Co., of London, and shown at the Royal Naval Exhibition in 1892, consisted of a strong iron frame supplied with a hose-box at the forward end, and supporting at the rear a Siemens 20-horse-power motor, coupled to a Merryweather rotary pump by means of helical gear. The motor ran at about 1000 revolutions, and, by means of the gearing, the speed of the pump was reduced about one-third. The engine was to be drawn by horses, and plenty of room was provided for carrying the necessary men on the engine. Current was to be supplied by means of underground feeders with connection boxes at regular intervals. These connection boxes or plugs were intended to be in the form of posts, their tops provided with locked caps. The engine carried a flexible concentric cable, which could be connected to the wires in the post by simply unlocking the cover and screwing on a cap or connecting union attached to the cable.



ANOTHER EARLY ENGLISH FIRE ENGINE.

Similar engines have been built in Germany, and some years ago an electric fire engine was constructed also in the United States. This engine was devised by Mr. S. S. Wheeler, of New York, and consisted of an ordinary Silsby crane-neck, steam fire engine truck, upon which was placed a Sprague electric motor, directly attached to a Silsby rotary pump, the motor and pump being placed longitudinally. The engine

was equipped with suction hose, air chamber and other accessories, like a regular steam fire engine, and was intended to be drawn by two horses. It was also equipped with a regulator and switch for the electric motor, and several hundred feet of flexible wire cable were carried on a reel for attachment to electric connection boxes. These were to be located adjacent to the water plugs throughout the city districts in the manner previously mentioned. The engine, upon trial, gave very good results, and is now in actual use at the factory of the Crocker-Wheeler Electric Company, at Ampere, N. J.

A GERMAN FIRE PUMP OF 1615.

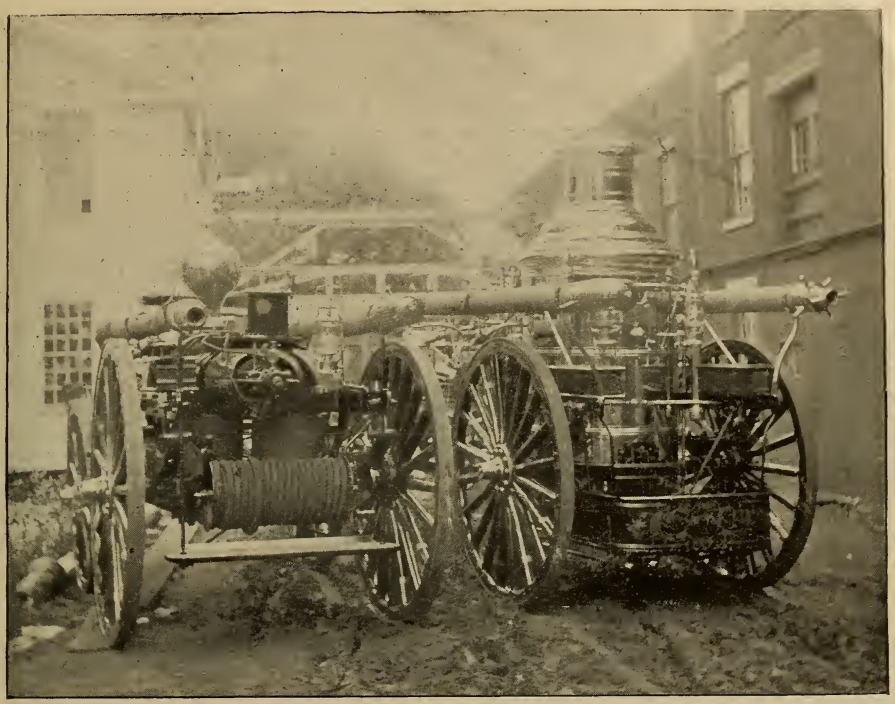
FROM DECAUS.

From recent reports it appears that the city of Lynn, Mass., is to have an electric fire engine. Details are not available, but it is to be presumed that the design will be on about the same general lines as those here referred to The writer also has devised an electric fire engine, consisting of a suitable truck upon which is a spring-supported platform or cradle, holding a motor which operates two rotary pumps. The engine is supplied with flexible cable and the motor can be regulated from either side of the engine.

The electrically-operated fire engine would possess a number of advantages over the steam fire engine. Not only would it be much lighter and smaller for the same capacity, but it would be simpler and more efficient and not necessitate any waiting, as at present, to raise steam. In fact, as soon as the engine arrived at the fire, the motor and pump could be started at once by simply making the connection with the plug or switch boxes. Aside from this, it would be free from all smoke, dust, cinders and ashes, which are such objectionable accompaniments of steam fire engines.

There can be little question that an electric portable fire engine would be efficient and thoroughly practical, were the question of current supply settled, and were it not that this part of the outfit, if poperly installed and used for its special purpose only, would necessitate so great an outlay of money. But it is not absolutely necessary that a separate plant should be installed for the electric engine system. Where a city or district is well supplied with electric lighting, railway or power mains, distributed fairly well, and all of the same nature and voltage, these could be used for current supply by connecting them at intervals with suitable tap or switch boxes which would be easily accessible and to which the engine motor could be connected. It would not be necessary to have these switch boxes very close to the water plugs ; they could be some distance away and the cable, carried by the engine, would be attached to the nearest one. The electric supply mains and switch plugs or boxes would thus have to be only in the principal streets and avenues. The engine could be connected to any water plug without any regard to the location of the connection boxes, as enough flexible cable could always be carried on the engine to permit operating the engines at quite some distance from the distributing mains.

Although such a method of distribu-



AN ELECTRIC AND A MODERN STEAM FIRE ENGINE.

tion would be easily applicable to places where the electrical wires and systems of lighting and power distribution fulfill the conditions as above, it would be best to supply the electricity from some source, separate and distinct from any commercial interests, and operated by the municipality, and perhaps solely for its special purpose.

The generating station could be very similar to the stations used to supply light and power for ordinary commercial purposes, and in large cities several such central stations might be used, each one supplying its own particular district; but the distributing wire should be so arranged as to permit of inter-connection with that of any other district, so that, if it were necessary, two or more stations could supply current to any one district.

It would not be necessary to at once install an electric system throughout an entire city; certain districts could at first be equipped, and the system gradually enlarged. Electric fire engines of a smaller capacity would also be particularly applicable to large manufacturing plants, railroad and shipyards, etc., and the distributing system could readily be arranged and supplied from the electric light dynamos.

# DIRECT ELECTRIC-DRIVEN MACHINES.

The law of economy traverses the line of least resistance.

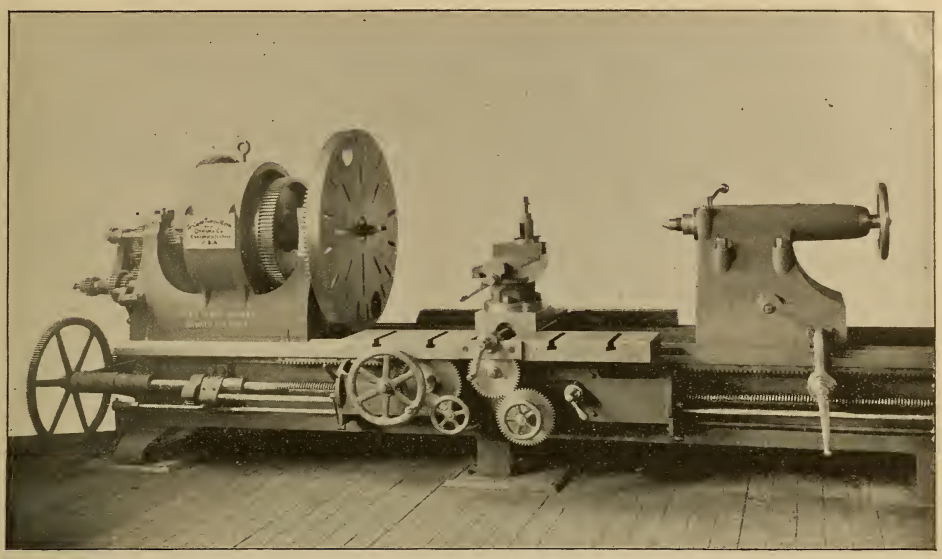
*By W. E. Hall.*

THE use of electricity to drive isolated parts of plants, and even individual machines, has had such an impetus recently that it is almost impossible to present the subject fully, and, at the same time, give the many practical applications that have been made, in the limits of a magazine article. The applications in the different cases are, however, in a general way very similar, and the more extended the use of electricity becomes, the more thorough is the appreciation of the ease with which it can be handled. Compare, for instance, the running and maintaining of an independent engine, with its accompanying steam line, with that of an electric motor, and the ease with which an electric switch can be manipulated, in comparison with the operation of a clutch or, what is even more objectionable, the shifting of a belt! If we stop to consider that "the man is yet unborn that duly weighs an hour," we realize more fully the importance of studying closely the element of time that enters into every operation, be it mental or physical, with the object of reducing it to a minimum, thereby producing the desired result in the most efficient way. Those who are striving in this direction are making necessities out of luxuries and are bringing within the reach of the many that which previously was obtainable only by the few. Bodies organized to work contrary to this law can meet with but one end—failure.

The use of electric motors to drive manufacturing plants has practically reached two stages:—1st: Where motors are employed to drive a main line of shafting, or sections of it, or to drive isolated parts of plants; or the entire elimination of shafting, the motors in this case being belted to groups of, or individual, machines. 2d.: Where individual machine tools are driven by direct-connected motors.

There have been many cases of the use of electric motors to drive lines of shafting or isolated parts of plants to prove conclusively the remarkable increased efficiency obtained, especially where the conveyance of steam for a long distance was necessary. This has led to a more thorough study of the amount of power absorbed by line shafting and countershafts. The minimum loss that can be looked for, and this is obtained only in exceptional cases requiring constant vigilance, is 25 per cent. of the total power developed, and more frequently runs as high as 65 to 70 per cent. A safe average would be from 40 to 50 per cent., although the actual loss must be determined for each and every case. With the use of electric motors, when properly designed and proportioned for the work, as, indeed, is as necessary in electrical work as with any other problem of mechanics if the best results are desired, this percentage of loss can be materially reduced. An inefficient result must be expected with bad electric engineering just as with a poorly arranged case of millwrighting, but, the electrical proportions being once obtained, there will, within reasonable limits, be no decrease in efficiency from deterioration.

The advent of electricity for such purposes seems to have enabled managers to realize more fully than ever before the loss accompanying what was heretofore generally accepted as the most efficient method of furnishing



A 42-INCH ENGINE LATHE, WITH DIRECT-CONNECTED MOTOR.

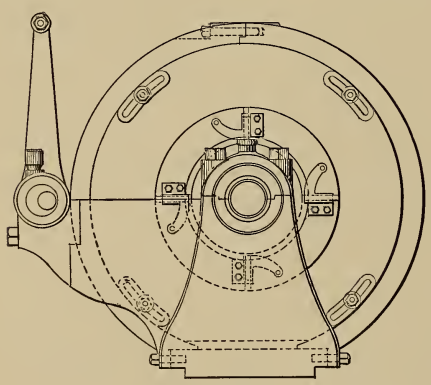
power to the individual machines of a plant. The use of electric motors in the place of shafting and on isolated machines, where the motors are belted direct to the isolated shafts or to the machines, has been sufficiently extended to render the verification of the results obtained unnecessary. It is no exception to find a reduction of 50 per cent. of the power consumed. This is not due entirely to the saving of loss through friction, but also to the advantage gained by the intermittent action of machinery of every kind. Tests show that where the motor drive has been substituted, the machines are in operation but little more than one-half the time, or, more correctly stated, the power required is only about one-half the total average power of the machines when doing work. As remarkable as these results may seem, sufficient data are on record to prove their correctness.

In the case of direct-driven electric tools, the conditions are somewhat different and more complicated. In the first place, the work done on machine tools is of a variable nature and requires a range of speeds, thereby necessitating for the direct drive, a variable speed motor and, to obtain the most economical results, one that will give a high and practically constant efficiency for the range of speeds of the machine to which the motor may be attached. In this particular the requirements are a little in advance of the electrical art; for, while the Leonard system fulfills all these requirements most admirably, its cost, when used on separate machines, makes it prohibitive. The use of the rheostat is also excluded, notwithstanding that some claim the loss accompanying its use to be small in comparison with the other advantages gained; yet it fails to fulfill the conditions that will lead to the most general introduction of the direct motor drive. Radical changes are made slowly, and it is only by presenting the improvement in its most favorable light that they can be reached. Besides, the variation of the average machine-tool would probably range from ò to 4 horse-power, and a motor driving it would be working on an average of about 2 horse-power, representing, approximately, by the use of the rheostat, a loss of 50 per cent. of the power actually required to drive the tool.

If a slow-speed motor is not used, the reduction from the motor to the machine

must be made by belting or gearing, either of which is more objectionable than the loss of efficiency through the lower speed. Belts are objectionable not only because of the obstruction which they form about any shop, but also because of slippage and the cost of maintenance, together with the general annoyance that always accompanies their use. Gearing of any kind always means a loss of power; it is used only in cases of necessity, and is avoided wherever the required results can be obtained by other means.

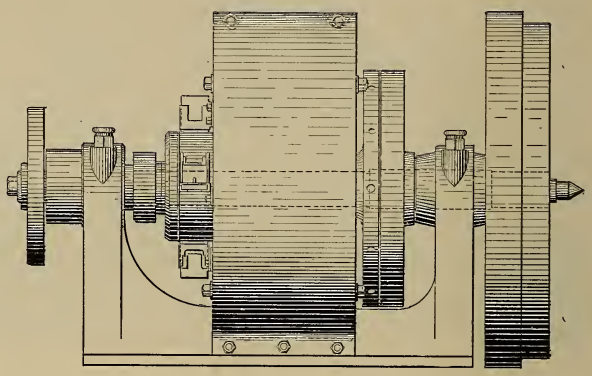
The conditions, then, requiring a variable slow speed motor of comparatively high efficiency, with the Leonard system excluded by its excessive first cost, and belting or gearing being objectionable for the reasons just stated, we are led to consider the motor with commutator field, with which system some satisfactory, practical applications have recently been made. This



END VIEW.

method has been decried from the inefficient results obtained by motors so wound and used on street cars, but the results are materially influenced by the proportions and details used.

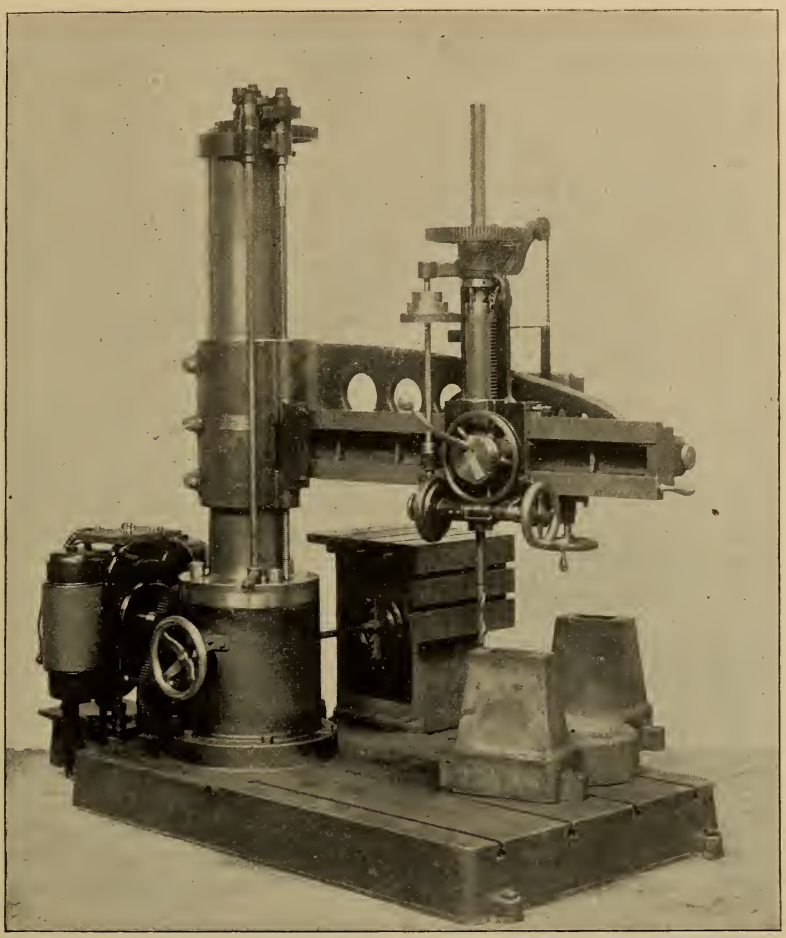
Further on will be found results of some crucial tests of two lathes, driven directly by electric motors having commutator fields, and with armatures attached directly to the lathe spindles, in place of the step cones. One was a 42-inch, and the other a 30-inch—both engine lathes. Volt and ampère meters were placed in the circuit sup-



MOTOR ATTACHMENT FOR A LATHE.

plying the current to the motors, and the readings were taken while the lathes were under various stages of work. From these the horse-power delivered to the lathes under the different conditions was obtainable. A prony brake was attached to the face-plate, readings were carefully made, and in this way the delivered horse-power was found. The brake and electrical readings were observed simultaneously.

Records were taken for twenty-four different speeds and pressures for each lathe, and the average efficiency was determined from these readings. The conditions at the different speeds and pressures were arranged as nearly as could be in compliance with what would be called for in actual practice for the various positions. The combined efficiency of the 30-inch lathe and its motor showed, with back gearing, 69.5, and with belt speed, 71.3 per cent., or an average of 70.4 per cent. This small difference does not indicate the loss in the gearing, which would be much in excess of 1.8 per cent. The belt speeds were much higher than when the back gearing was used, resulting in a corresponding frictional and energy loss to maintain the speed. The average efficiency of the 42-inch lathe with back



A DIRECT ELECTRIC-DRIVEN RADIAL DRILL.

gearing and belt speeds was 65.83 per cent. In this case the gearing and face plate were much heavier in proportion than those of the 30-inch machine.

The heavier and more powerful tools will show a lower efficiency on account of increased internal resistance, but this loss is by no means commensurate with the greater economy obtained by the ability to turn out larger quantities of work. The motors were then tested for efficiency, regardless of the loss in the machine, by running them loose on the spindles, the armature supports consisting of the spindle bearings in the headstock. The friction of two closely fitted bearings, such as are necessary with the front and back ends of lathe spindles, would be more than those loosely fitted, such as are found in motor armature shaft journals. The motors ran from 58 to 275 revolutions per minute and gave at these low speeds a minimum of 76 and maximum of 77.2 per cent. efficiency. These tests were made after the motors had been in use on the lathes for from six to ten months. In the case of the 42-inch machine the tests covered a range of from 1.3, as a minimum, to 6.4 horse-power, as a maximum, at the face plate, with 10.19 horse-power delivered to the machine. The motor on the 30-inch lathe was somewhat smaller, and the maximum

horse-power obtained at the face-plate was 4.46.

It will be noticed at once that the maximum horse-power delivered at the edge of the face-plate of these two lathes is in excess of what can be obtained from any belt-driven machine of the same swing. The question then arises :—"Is this not also a case of concentration?" As stated, the motor occupies the place of the cone in the headstock and practically requires no changes in the lathe proper ; in other words, it does not occupy any more space. In any machine-tool the object of the design is to give sufficient variation of speed, with ample power, so that it can handle the full range of work economically. An increased number of speeds means either a machine occupying an increased amount of dead space, or a narrower belt. Both have their limits in practice.

A casting was placed on a 42-inch, belt-driven lathe of exactly the same patterns as the machine that was driven by an electric motor. The maximum cut (given in a comparative sense only, as it will vary with the nature of the metal) that could be taken was $\frac{11}{16}$ of an inch deep and 0.08 inch wide. The same casting was then placed on the electric-driven machine, and, at the same speed and feed, giving, therefore, the same pressure at the edge of the tool, showed a consumption of 3.1 horse-power. The cut was then increased to $\frac{13}{16}$ of an inch deep without any drop in the speed. It was then further increased to $1\frac{3}{32}$ inches, when the motor decreased in speed at the edge of the tool from 38.7 to 35.4 feet per minute, representing a drop of about 8 per cent. The feed remained the same in all cases.

There was delivered to the lathe, when doing this heavy work, 7.28 horse-power, while the brake showed 4.79 horse-power. By the use of the brake three additional horse-power were put on the motor without its becoming unduly heated. The lathe was more than amply heavy in all its details to withstand the maximum power which the belt was capable of giving, and the above tests were not intended to indicate that such excessive cuts could be taken on the general run of machine tools by substituting the electric drive. Continuous work as heavy as the maximum obtained by the motor is to be deplored as unduly straining the tool and injuring its efficiency for accurate work. But the tests showed clearly, from the heaviest cut that could be taken, that in the same space an electric-driven machine can be placed that has about 120 per cent more power than a belt-driven tool.

When taking the cut $\frac{11}{16}$ inch deep the pressure at the point of the tool was 1960 pounds ; at $\frac{13}{16}$ inch the pressure was 2750 pounds, and with a cut $\frac{29}{32}$ inch deep it was 3878 pounds. With the cut $1\frac{3}{32}$ inches deep the pressure ran up to 4467 pounds, the friction in this case drawing the temper of the self-hardening steel of which the cutting tool was made. No lubricant was used in any of these tests, and from experiments already made there seems to be no doubt that a system of lubrication can be used to prevent the over heating of the cutting tool for any pressure that it may be advisable to use on a machine tool.

As regards the cost of equipping a machine with electric drive, let us take the case of the 42-inch lathe. Equipped in the ordinary way, this requires approximately eight feet of main shafting, with one coupling and two hangers, main line pulley, belt from main line to countershaft, countershaft complete with timbers, belt from countershaft to machine, and the cone on the lathe spindle. Against this we find the electric motor with its accompanying switch, about eight feet of conductor wire, and the wiring from the conductor to the motor. This makes the motor-drive, in first cost, amount to about $100 more per machine than the belt, the difference depending on the nature and size of the machine. In a planer it would not be any more.

More efficient motor results can be obtained by using a motor of higher speed and placing it overhead, and running a single belt from the motor to the machine. But this, again, is open

to the objection accompanying all overhead rigging, especially where traveling cranes are used for handling the work. As previously stated, however, the item of wear and tear on the belting would more than counterbalance the loss in the coal pile from the use of the slower speed motor.

An objection has been raised to direct-driven machines on the ground that trouble would arise from magnetic action, the chips adhering to the bed and other parts of the machine, cutting the shears and bearings. Without going into detail, it can be stated from actual test that with a properly designed motor, no such magnetized condition exists. Even the top cap of the field will not attract the smallest piece of metal of any kind. We find, then, in the application of the variable speed, direct electric drive to the various kinds of machine tools, without the use of the rheostat, the following advantages :—

1st. Less loss than in the use of belts from the main line to the countershaft and from that to the machine, which difference increases as the belt deteriorates, the loss in the electric drive being about 20 per cent. with slow speed motors, but less than that where it is possible to place the motor overhead and drive from that position, using a wide belt to the machine.

2d. The exclusion of countershafts and overhead belting, thereby allowing the free and unobstructed use of overhead traveling cranes.

3d. Greatest range of speeds. In the 42-inch lathe the number of speeds with belt drive (triple geared) was fifteen and with the electric, twenty-seven, both in either direction.

4th. Instant change of speed from maximum to minimum, or to any intermediate, and also instant reversal. With the belt-drive a change of speed requires either a shifting of a belt or a change of the gearing, both consuming time.

5th. Reduction or eliminating entirely the wear and tear on belts and their accompanying loss in transmission. The electric drive is practically of the same efficiency until worn out.

6th. No power is consumed by the machine or any of its accompanying parts, such as countershafts, except when actually in use and doing work.

7th. The machine can be placed in any part of the shop, and at any angle with the line shaft, thereby utilizing to the utmost all the floor space, and allowing the machine to be located in the most convenient place or position for the work which it has to do. This is also advantageous in cases where it is more convenient to move the machine than the work.

No. 4 shows, from actual experience, an increased output of 25 per cent. This is a conservative figure. There are so many places where this feature has such advantages that it would be impossible to cite them all here. Let us consider one only, when the work is about the full swing of the machine and is to be faced. The belt is placed on the proper step of the cone, giving a fixed number of revolutions, which is maintained until the tool reaches the centre ; but as the diameter of the work on which the tool is cutting gradually decreases, a corresponding loss of time results. This can be obviated only by shifting the belt from one step of the cone to another, which would consume more time than could be gained by the change. With the electric drive and variable speed motor, the speed is varied for the change in diameter by a rod controlling a switch, the former running along the front of the machine or anywhere within easy reach of the operator. By this means the number of revolutions is varied and the cutting speed remains constant for the various changes in diameter of the work. This feature also allows the instant reversal of a tool which is particularly adapted to cases where but part of a circumference is to be finished.

The variable speed motor is equally applicable to planers and is now in use on such machines. Its efficiency on this type of tools is plainly evident.

One of the accompanying illustrations shows the 42-inch lathe on which the tests were made ; another illustrates the method of applying the direct drive

to a radial drill. The cut of the head-stock shows the manner of attaching the motor to a lathe.

As far as the writer is aware, the above results are the first obtained with the direct electric drive without the use of belts. The same end can, no doubt, be reached through mechanical means and the use of a constant speed motor, or by even other means. It is a question for future determination as to which method will give the most economical results. From the preliminary tests and the results obtained it appears that electricity has found a field in its application to direct-driven machine tools larger than any that it has yet been called upon to fill.

The writer begs to express his appreciation of the kindness of Mr. J. S. Neave, of Cincinnati, who conducted the tests of the direct-driven lathes.

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# A PIONEER OF TECHNICAL EDUCATION.

*By Prof. A. H. Sexton.*

HAVING reached a mountain top after a tedious climb, it is pleasant to look back over the path along which we have come, and note the steps by which the summit has been reached ; and it is often well to rest before the journey is over and to look back at the ground which has been covered, as well as forward to that which has still to be gone over. This is true of all advance, and our journey onwards is likely to be helped by halting to consider the progress which has already been made.

Technical education is one of the things in which enormous progress has been made during the last fifty years, and it is of special interest, therefore, to look back to the origin. Like in all social movements, it is quite impossible to give an actual starting point. It is like the course of a river, the result of an enormous number of rivulets flowing in the same direction and mixing their waters in a common stream. Trace it upward, and perhaps we find one brook or rivulet of a little more importance than the rest, perhaps retaining the name of the river almost to its very source ; or one rising a little higher up the hillside than the rest; and yet, dam this one up or divert it, and the river would flow on with little change.

The river is not made by the one brook, but by the union of all. So, in tracing back the stream of technical education, we find that it, too, has been made by the union of the efforts of a large number of workers, and, whilst looking at the whole, we cannot see the results of the individual work of each. Yet, as we trace it back, we can ascertain, to a certain extent at any rate, what each has done and where the stream of effort flowed in to swell the current ; and, going back as far as we can, we find one man whose work was of so much importance that we may almost regard him as the originator, just in the same sense as we may regard the rivulet which rises farthest from the mouth as the source of the river ; and this man is John Anderson, of Glasgow.

John Anderson was professor of natural philosophy in the University of Glasgow from 1760 to 1796, and by his work in the University, and still more by the provisions of his will, he did much to give a start to what we now call technical education. As to his career before he was appointed to the University, nothing need be said. He was first professor of oriental languages, but it was not till his transference to the Chair of Natural Philosophy that his life work can be said to have commenced.

He was not by any means a typical university professor ; that is, he was

not absorbed in the scholastic or purely intellectual side of his work, but inclined very strongly to the practical. He preferred mixing with men to the seclusion of the study; he preferred things to words, and the study of facts to the mere study of books. He spent what time he could spare from his duties, in the works where the various industrial arts were carried on; he visited the shops of the carpenters, the mechanics, tool makers, smiths and others; he watched the men at their work; he became the friend of the foremen and the workmen; and in that way he acquired a real, practical knowledge of the work which was carried on, and a clear insight into the needs of the men connected with it.

JOHN ANDERSON.
FROM A MEDALLION BELONGING TO THE GLASGOW TECHNICAL COLLEGE.

He saw that, good workmen as they undoubtedly were, they were absolutely ignorant of the reasons for the various operations which they had to perform in their daily work, and that, in most cases, a little knowledge would enable them to improve their methods of work in many ways; and he set himself to consider how it would be possible to provide the instruction which, he saw, was needed, for he felt that if the instruction were provided the men would take advantage of it.

In the middle of the town stood the University, the seat of learning, with its staff of professors and lecturers, and ample means of teaching. Why should it not shake itself free from the traditions of antiquity, the dry-as-dust literature and theology of past ages? Why should it not become the home of science and the industrial arts, and provide instruction, not only for lawyers, doctors and ministers, but for those who were engaged in the arts, and on whom, therefore, the industrial supremacy of the country depended?

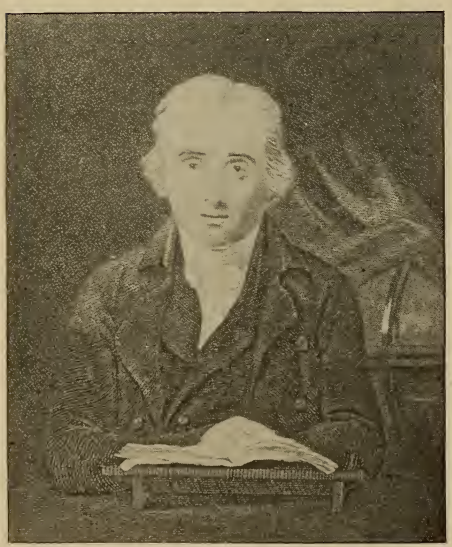
Anderson was not a man to be content with speaking or thinking. He acted. There was no course of instruction in science suitable for the workmen, for the usual course of natural philosophy presupposed a good knowledge of mathematics. He, therefore, started one. On four days a week he gave his usual lectures for the University students, and on the other two he arranged to give a new course in which the subject should be treated experimentally, and for following which a knowledge of mathematics would not be essential. It was to deal with facts and things, not words and symbols, and was probably the first course on what we now call "Experimental Physics" ever delivered in a university. The class was intended not only for students in the ordinary restricted sense of the word, but for business men, workmen, foremen,—for all who wished to learn.

Among the mediæval customs which have been retained by the universities, dating from the days when the university was a close corporation and it was necessary to distinguish those under its jurisdiction from those resident in the town, was that of wearing a gown. The Glasgow gown is specially conspicuous, being a scarlet cloak reaching nearly to the knees. Even to-day this cloak is insisted on for students attending some classes, and anyone appearing without it cannot count his attendance. Anderson was clear-sighted enough to see that to put a workman attending his

lectures into the scarlet gown would be an absurdity, and that, therefore, to insist on the gown would be enough to prevent the success of his class. He therefore decided to abandon it, and he always spoke of the class as his "anti-toga" class.

The class prospered, and for over twenty years it occupied the chief attention of the professor. He worked at it as a labor of love. He published his "Institutes of Physics" to help his students, and he paid constant attention to the development of the industries of the town, so that he might not lose touch with the workmen. The non-insistence on the gown was, of course, an offense in the eyes of the authorities, but Anderson went still further, and allowed students who had not time to change their clothes, to come as they were, in their working dress.

Glasgow University had connected with it at that time two men of great



DR. T. GARNETT.
FROM AN ENGRAVING.

importance who afterwards attained world-wide fame. Black, the lecturer in chemistry, was laying the foundation of the modern science and was introducing experimental methods of teaching; and James Watt was mechanician to the University, having a workshop within its walls. One of the duties of the latter was to repair the apparatus belonging to the college and, no doubt,

THE OLD GLASGOW UNIVERSITY.

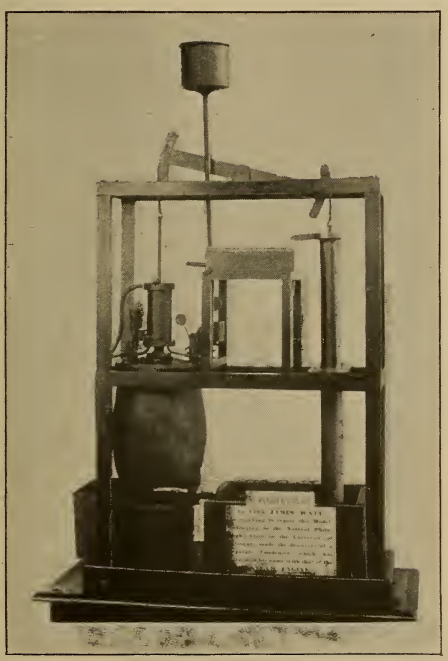
he also devised and made new apparatus as it was required. Anderson and he must have been thrown a great deal into contact. We know nothing of the intercourse between the two men, but we can well imagine that it would have had considerable influence on both of them. Contact with such an energetic, quick-witted mechanic as Watt would, no doubt, quicken Anderson's interest in mechanics and in the education of workingmen, whilst, on the other hand, Anderson's scientific knowledge may have been of great help to Watt.

Among his apparatus Anderson had a model of Newcomen's engine which he used for class demonstration. It would not work, and was, therefore, taken down to Watt for repair. It was while working at this engine, and thinking out how it could be improved that Watt hit upon the idea of the separate condenser which was such an important advance in the history of the steam engine, and on which his fame and fortune depended to such a large extent.

It was hardly to be expected that a man with such ideas as Anderson had should not meet with opposition from his colleagues; indeed, his whole life was embittered by their hostility,—hostility, it is only fair to say, for which he himself was, to a large extent, responsible. He was a man not to be deterred by opposition or hostility, but went

steadily on in the path which he had chosen.

Apart from his educational work, two characteristics of Anderson may be noted,—he was intensely democratic; he believed in "the people," and openly expressed his sympathy with the French Revolution, and he had an enthusiasm for military things quite unusual, except in a soldier. This dated from 1745 when, as a lad, he had enrolled in the Stirling volunteers to de-



ANDERSON'S MODEL OF NEWCOMEN'S ENGINE.

fend that town from the Pretender. His sympathy with republicanism led him to suggest the use of balloons for carrying republican literature from France to Germany over the wall of troops which guarded the frontier, and his military ardour led him to design forts and to invent a cannon arranged so as to take up the recoil,—an invention which, though overlooked by his own government, was taken up by the French.

As time wore on, he gave more and more attention to his technical teaching and began to arrange plans for carrying on the work after his death. He spent time and money in collecting a museum of apparatus and specimens for teaching purposes, and he made a will leaving all his property for the carrying on of his work. In 1796 he died, and the trustees nominated in his will at once set about carrying out his views. He had carefully thought out the whole matter, and his plans were very complete. All details were laid down, and the first professors were nominated. But alas! when it came to carrying out the scheme there were barely £1000 in money for it all. Public-spirited citizens, however, came to the rescue and the trustees were able to start almost at once. Anderson had put in the will that, if it were not possible to carry out the whole scheme, natural philosophy was to have the preference, and it was, therefore, decided to appoint a professor of that subject, and not, at the outset, to assume the name of University, but to start as Anderson's Institution.

W. Meikleham, Anderson's assistant, who had been nominated in the will as professor of natural philosophy, did not take office and the trustees appointed Dr. Garnett as the first professor. Garnett commenced work in 1796 and his success was instantaneous. He commenced day courses of lectures similar to those which Anderson had given at the University, and he also commenced evening classes for workingmen which were attended by very large numbers, eight hundred being enrolled during the first session, and nine hundred and seventy during the second. These seem to have been the first systematic evening classes ever held for instruction in science. Another innovation, made according to the instructions in the will, was the opening of all the classes to women.

Anderson's ideas of education were sound and thorough, and he did not intend his university to be restricted to the teaching of only one class of subjects. It was to be a complete university, and was to be free from all class distinctions and all such traditions as

he had felt hampering his own work. Had it been possible to carry out the plans in their entirety, his university would have been far in advance of anything then existing in the world. As it was, success was greater than could have been anticipated, and if the new institution did not do all that its founder wished as an educational institution, it did more than even he could have imagined possible for the development of education.

Garnett removed to London in 1799 to become first professor in the Royal Institution which had been founded by Count Rumford much on the lines of Anderson's Institution, and he was succeeded in Glasgow by Dr. Birkbeck, who was followed by Dr. Ure. In due time the growth was sufficient to allow the trustees to assume the name of University. This was done in 1828 on removal to the buildings which are still occupied. In 1877 the name was changed to Anderson's College by act of Parliament and in 1886 it became, by union with other institutions, the Glasgow and West of Scotland Technical College.

In 1823 a number of students seceded and formed the Glasgow Mechanics' Institution, the first in the world, and from this sprang the long list of similar institutions which have done so much for the education and uplifting of the working population.

Thus did Anderson's work in the University of Glasgow lay the foundation of popular education. Anderson saw what was wanted, but he was before his time, and, therefore, his work was but partially successful. So clearly, however, did he see the needs of the people and how they could be met that from 1796 to 1877 the college was carried on strictly in accordance with the provisions of his will, and only small changes were made. The institution which he founded soon became a veritable people's university and now, after nearly a century of existence, it is still doing well the work for which he founded it, and is giving scientific instruction to those who need it in their daily work. The name technical education was unknown in Anderson's time, but his work and the work which he directed to be done under his will were excellent examples of what such education should be.

# TOOTHED GEARS, OR ROPES AND BELTS?

*By Wm. H. Booth.*

IT seems to be the fate of most mechanical contrivances to become stereotyped, after which improvement ceases. It is when the stereotyped form has been adopted that newer contrivances, the outcome of more modern modes of thought and work, displace the older fixed forms, and the displacement may take effect without any really good reason mechanically.

An instance of this may be cited in the almost entire abolition of toothed gears for heavy driving purposes by belts or by ropes. The alleged reasons for the transformation have been the frequency of breakdown of the toothed wheels, their noise and their expense, and yet it is very doubtful if any one of these reasons can be held up as a mechanically sufficient reason in face of present knowledge. In the first place, the stereotyped rule for the length of a tooth was that it should be three-fourths of the circumferential pitch, and one has but to turn to the pages of Rankine or other works to find the statement that the strength of a wheel depends entirely upon the resistance of any one tooth to a blow upon one outer corner. Such teeth, in fact, were readily knocked off.

Further, the length of the arc of contact between the wheels with such long teeth is very great and the friction, especially as the teeth approach the line of centres, is severe, and that such wheels were noisy in working admits of very small wonder. As all large mill gears were used in the rough casting, without any further dressing than that necessary to remove any lumps or scabs, the form of the teeth was always such that, when first put to work, they made contact on an arc each side of the pitch line only about one-eighth the tooth length, and it would be years before a large pair of wheels showed wear all the way to the points of the teeth.

The so-called faults of the teeth were faults of design and the tendency, now, is to use teeth not above one-half their former length, and, of this shortened length, the corners, well rounded, form a considerable proportion. Indeed, for large wheels, as, for instance, a pair of 24 feet and 6 feet diameter which, at one time, might have a pitch of tooth of 6 inches and a tooth length of 4½ inches, the pitch need not be above 4 inches on a modern wheel, and the tooth length one inch, the smaller pitch being stronger in a short tooth than the big pitch with the long tooth. With reduction of pitch and length comes reduction in the severity of the blows when running and also a large reduction of weight, and, consequently, a greater safety in faster speeds, so that there are no reasons why the speed of a well-developed, toothed wheel should be much less than the speed of a rope or belt pulley.

An incidental reason for the popularity of belt or rope gearing has been the steadiness of turning effort which has been noticed to accompany them ; but this has been merely a question of weight and speed of rim, heavy rims being due to the necessary great breadth, and the principle of the rope or belt having only a merely accidental connection with the steady turning effect. Should toothed gearing again come into more extended use, it will probably be in the involute form of continuous curved face that we shall see it, and with short teeth of as fine a pitch as is consistent with strength, the modern idea of a toothed wheel being that there shall be one pair of teeth only in contact at one time ; but one pair must

not leave contact before a fresh pair engages.

Length of tooth has been handed down to us from the days of imperfect adjustment and slow speed, but it is out of harmony with the conditions to be met with to-day. Even with the imperfect teeth so far employed, it is generally admitted that the loss of friction is much less than with ropes, and the first cost of rope and belt gears is by no means so much less than the cost of ropes as it was once thought to be.

The higher piston speeds of the rope-geared engines have, no doubt, enabled them to deliver an equal power at the second motion shafting with less coal than the toothed-gear engines, despite the less friction of the latter; but with improved wheels this advantage would disappear. Designers of rope gearing appear to overlook the very slow increase in the horse-power of a rope when the speed passes 4000 feet per minute. At this speed the stress due to centrifugal force grows rapidly, and, at 5000 feet speed, increases faster than the speed increment. Now, at the higher speeds the frictional losses, in which may be included the loss due to differences of pitch-circle of the ropes, the internal friction of bending the ropes, and the pulling out of the ropes from the wedge grooves, are all increased, probably in just about the ratio of the length of ropes passing any given point. Very high speeds are, therefore, to be deprecated as calling for too large diameters of pulley, while for such work as cotton mill driving, it is likely that the flywheel energy is now greater than necessary.

In olden times, single cylinder beam engines of 300 indicated horse-power were worked at less than 20 revolutions, with flywheels of less than 10 tons of rim weight. At present, three times the horse-power is allowed three times the rim speed, with rims of forty tons, and two compound engines on 90-degree cranks. The fluctuation is reduced to probably less than one one-hundredth of its old amount, the piston impulses being also trebled in each cylinder, and the regularity of turning being increased both by the inertia action and by the compound principle. Indeed, there is no comparison on this point, and, therefore, attention may very well be drawn to the danger of overdoing the speed in belt and rope connections.

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## STRAIGHTENING A LEANING CHIMNEY.

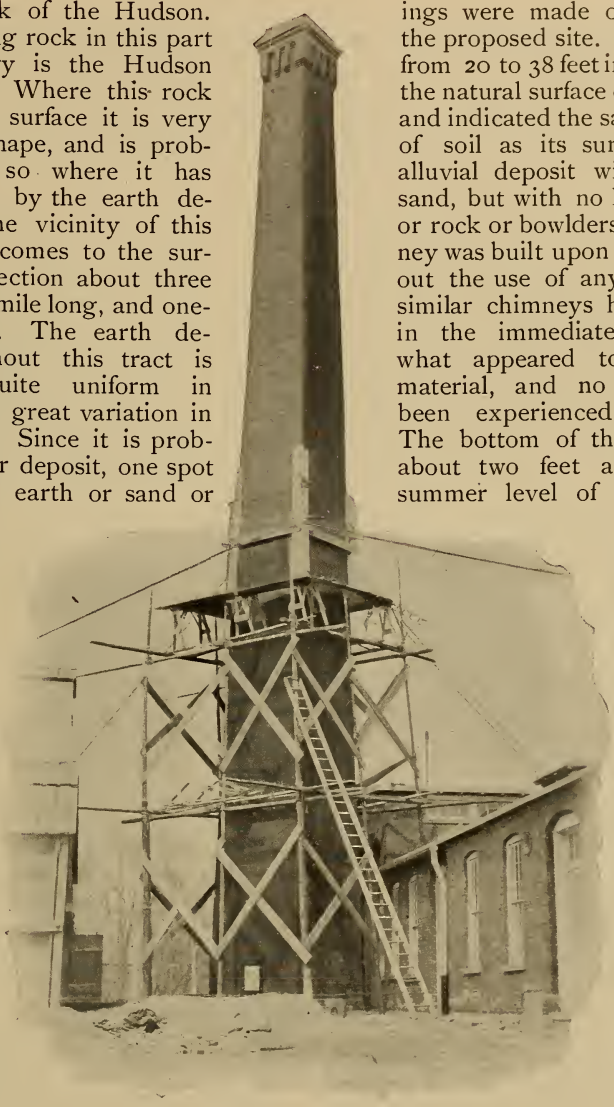
*By Joseph C. Platt.*

IT will perhaps be interesting to those having similar property, or to any who may have similar work to do, to know how a brick chimney 100 feet high, which leaned about 28 inches, was made plumb. The chimney belongs to the Ormsby Textile Company, of Waterford, N. Y., in the United States, and the operation, as here described, was detailed in substantially the same manner in a paper recently read before the American Society of Mechanical Engineers.

All the measurements were given to the writer by the owners. The chimney was erected in 1893. Soon after its completion it was found to be considerably out of plumb; and when first measured was found to lean about 16 inches, and a few days later 22 inches. Then the rate of increase of inclination became less, but in March, 1894, it was 28⅛ inches out of line, and it was decided to attempt to straighten it.

The factory to which the chimney is attached stands on the north side of the north outlet of the Mohawk river, and distant perhaps one-third of a mile from

the west bank of the Hudson. The underlying rock in this part of the country is the Hudson river shale. Where this rock comes to the surface it is very irregular in shape, and is probably equally so where it has been covered by the earth deposit. In the vicinity of this mill no rock comes to the surface over a section about three quarters of a mile long, and one-quarter wide. The earth deposit throughout this tract is apparently quite uniform in quality, yet a great variation in it is possible. Since it is probably all a river deposit, one spot may be good earth or sand or gravel while another may be largely vegetable matter and much softer.



STRAIGHTENING A LEANING CHIMNEY.

The chimney proper is rectangular in plan, built of brick, 9 feet 6 inches square at the bottom and 5 feet 4 inches square at the top; it is 100 feet high and has a central flue 3 feet square. The estimated weight of this is 206 tons. It stands upon a foundation which is 14 feet deep, the lower 4 feet being of concrete about 14 feet square, on which rests heavy stone-work 10 feet high, 14 feet square at the bottom and 9 feet 6 inches square at the top. The weight of the foundation is about 149 tons, making a total of 355 tons resting on 196 square feet, or about 1.8 tons per square foot.

Before commencing the work, soundings were made on all sides of the proposed site. These varied from 20 to 38 feet in depth below the natural surface of the ground, and indicated the same character of soil as its surface, a soft, alluvial deposit with streaks of sand, but with no hard material or rock or bowlders. The chimney was built upon this soil without the use of any piles. Two similar chimneys had been built in the immediate vicinity on what appeared to be similar material, and no trouble had been experienced with these. The bottom of the concrete is about two feet above normal summer level of the Mohawk river, but at the time of sounding in March it was submerged about four feet, it being found that the water rises and falls in the soil in the vicinity with the rise and fall of the river.

The work of straightening the chimney commenced on the 19th day of March, 1894. A scaffold was erected about the chimney and eight oak timbers, 6 inches by 10 inches by 10 feet, were placed vertically at the corners at a height of 42 feet above the stonework and 4½ feet below the centre of gravity of the brick work, the object of the oak timbers being to spread the bearing of the wire ropes over as large a section as practicable.

Wire ropes were passed around the timbers and another wire rope, 2½

inches in diameter, with an eye in each end, was fastened to the first-mentioned ropes at its upper eye. The lower eye was connected with a system of pulleys, secured to the dock at the river edge at a point 78 feet distant and directly opposite the direction in which the chimney leaned, the pulleys being made up of three sets of double and single blocks connected together in series, having three points of fastening to the dock, and having eleven pulleys in the system. Cables were also put out from the chimney on each side at right angles to the main cable, and having turn buckles to tighten them. There was also a guard cable in the rear.

The earth was then excavated on the high side of the foundation nearly half way around to the bottom of the foundation (a depth of thirteen feet) and the main cable was put under strain with the pulleys. By this means, in the course of three weeks, the chimney was brought back about 4 inches. Then, with a post-hole digger, 8 inches in diameter, 11 holes were sunk vertically in the bottom of the trench around the foundation, principally at the highest point, to a depth of from 5½ to 6 feet. At this time the water in the river stood up to within 1½ feet of the bottom of the foundation, the ground being soft to a depth of 4 feet; it then became very hard, showing that the strata supporting the chimney had been reached.

No movement or flow of the soil was discovered until the eighth hole was sunk 4½ feet and the tool withdrawn for clearance, when it could be reinserted readily only about 3 feet and headway made very slowly.

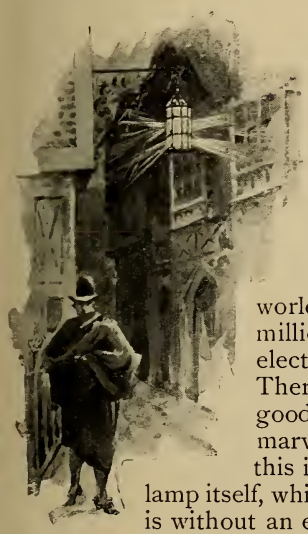
From this removal of the earth there resulted, within a few hours, a righting of the chimney to the extent of 5 inches. This increased to 8 inches by the next morning. The slack of the pulling rope was taken up as fast as the chimney moved, and the rope was kept under strain. By tightening up the pulley rope two or three times daily, in a week the chimney was brought back to 8¾ inches.

At this point, in similar manner, the post-hole diggers being reduced to 6 inches in diameter, about one-fifth as much more material was removed, immediately followed by righting the chimney to 4 inches, and from that point, after filling the holes with fine broken stone and gravel thoroughly rammed, by continued daily strain on the main cable, the chimney was brought back to plumb at the rate of a quarter of an inch per day. The turn buckles in the side cables were occasionally used to control any tendency toward lateral inclination. The work was accomplished without injury to the structure, and the chimney settled, in all, 0.598 of a foot.

In September, 1894, the chimney leaned nearly 2 inches towards the river, and away from the mill. This inclination has come since the trench was filled, and is, perhaps, the result of the weight of the material which filled the excavation on the high side of the foundation. This excavation was so large and deep that the material with which it was refilled weighed probably 80 tons.

# THE INCANDESCENT LAMP OF TO-DAY.

*By Johannes H. Cuntz.*



FIFTEEN years ago there was hardly a single commercial incandescent lamp in existence; to-day there are eleven million in use in the United States alone, while all over the world nearly twenty-five million are connected to electric lighting circuits. There must be some very good reason for this truly marvelous growth, and this is to be found in the lamp itself, which, in many respects, is without an equal among artificial lights. Its entire freedom from smoke and smell, its comparative coolness, the ease with which it can be placed in any position and in any place, its real beauty —both in itself and in the effect on its surroundings—all place the incandescent electric lamp far above any other source of light that man has hitherto employed.

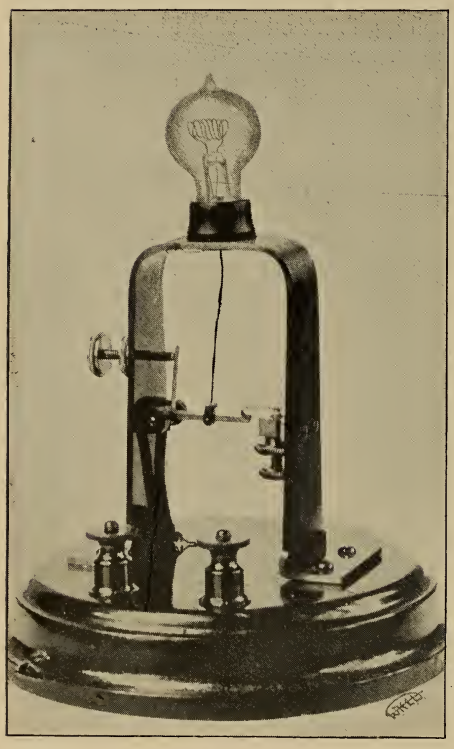
The small glass bulb and shining carbon filament have a history. They were not brought together in a day. Half a century ago men were striving to make an electric lamp consisting of a material enclosed in glass and heated to incandescence by an electric current, but for many years nothing that would stand the test of use resulted from their labors. The two chief difficulties to be overcome were: first, to find a sufficiently stable incandescing material, and, second, to produce and maintain a satisfactory vacuum in the glass enclosure.

For a long time attention was given mainly to refractory metals, such as platinum and iridium, but with these substances, the temperature of incandescence lies dangerously near the fusing point, and a slight increase in the current would cause them to stretch so as to become useless, or would even melt them altogether. Carbon was then tried, and as it burned more or less rapidly in air, intricate mechanism was devised to replace the carbon rods which were consumed by new ones, But this apparatus was always getting out of order, and attempts were, therefore, next made to place the carbon in a vacuum, where it could not be attacked by oxygen, and might last indefinitely. But here the great trouble was to produce and then preserve a sufficiently good vacuum. The glass receivers which contained the light-giving material were made in two or more parts, fitted together, and it seemed impossible to make air-tight joints. A very small leak admitted enough air to destroy the carbon with great rapidity.

So matters stood until about fifteen years ago, when the problem was finally solved by enclosing a thin strip of carbon in a continuous glass bulb with no joints, and leading in the current by platinum wires which give no chance for leakage, as platinum has the same rate of expansion as the glass itself. Since then, there have been no radical changes in incandescent lamps, though the methods of manufacture have improved steadily, so that it is now possible to turn out a much better lamp at a far smaller cost than in the early days of the art. From time to time renewed attempts have been made to fill the glass bulbs with some inactive gas, such as nitrogen, which would not attack the carbon, and to make the receiver in two parts, joined together with some cement-

ing material, but these efforts have not yet proved satisfactory.

The best, and, in fact, the only really efficient incandescent electric lamp of to-day is characterized by a continuous glass chamber, from which the air has been exhausted, and in which is the light-giving carbon filament, supplied with current by platinum wires sealed in the neck of the glass bulb. This seems a simple enough contrivance, but the



EDISON'S FIRST LAMP.

preparation of the materials and the putting them together involve the greatest care, and the present high state of the art has been attained only after many years of ceaseless labor and patient effort.

The carbon filament has probably caused more work and worry than all the rest of the lamp put together. It is the essential part. Until lately, the raw material for its preparation was bamboo, which was cut into thin strips and carbonized, but now some artificial compound of carbon is used, the exact nature of which is kept secret. This substance is cut into thin strips and is carbonized by heating in a suitable furnace. These carbonized filaments are of various lengths and thicknesses, some having a diameter of only five thousandths of an inch, and are bent into different shapes, the one most favored at present being the spiral. This form of filament starts from the leading-in wires in the usual way, and near the top of the lamp makes a spiral of one or more turns, which increases the effective length of the carbon and gives it a greater illuminating surface. At the largest lamp works in the United States, all the sixteen candle-power high voltage lamps—the most common size there—are now made with spiral filaments, as well as all lamps above sixteen candle-power. The more familiar "horse-shoe" and "hairpin" filaments, however, still have a place in the art, particularly in the smaller-sized lamps. Sixteen, twenty, twenty-four and thirty-two candle-power 50-volt lamps are still made in plain loops, and probably always will be.

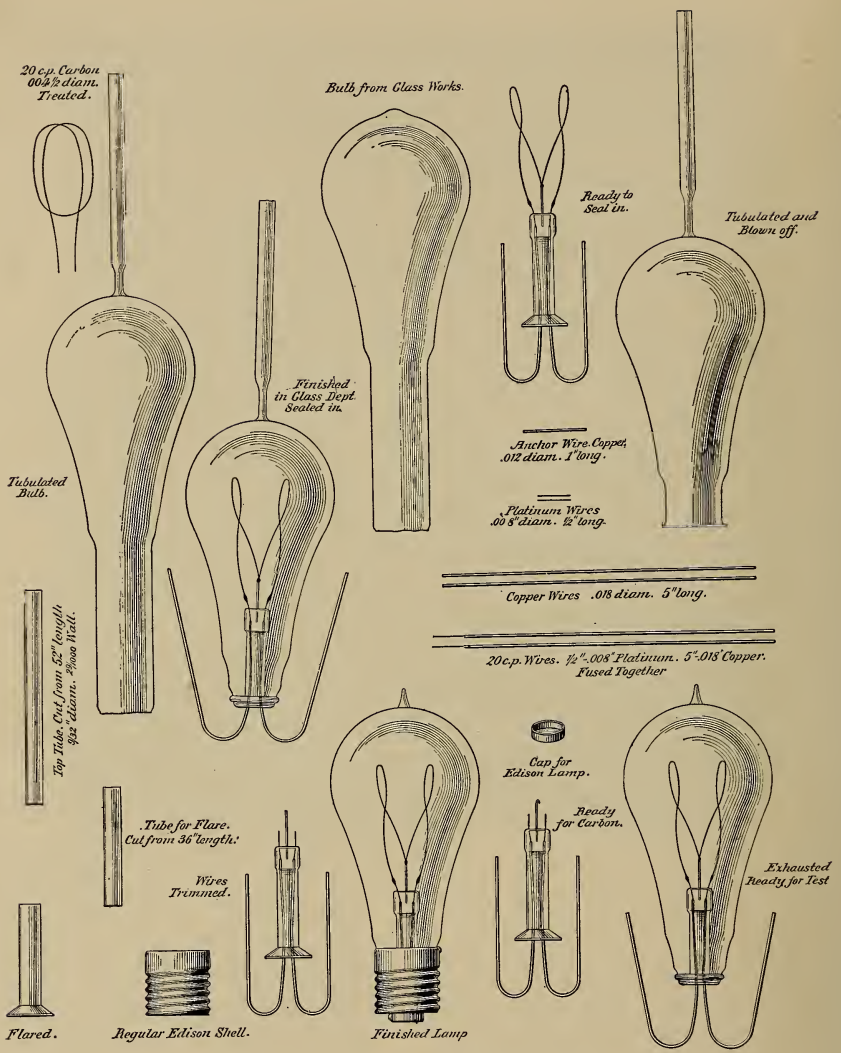
It is very important that the carbon composing the filament should be of uniform structure throughout, and to secure this homogeneous material, the greatest care is taken in all the processes of its manufacture. The filament is finally treated by being held, by the ends, in two brass clamps which pass through the stopper of a bottle, thus permitting the insertion of the filament into this bottle, which contains a rare vapor of gasoline. A current is then passed through the filament, heating it and decomposing the vapor, depositing the carbon constituent of the vapor on the filament. This brings the filament to the desired resistance and renders it uniform.

Leaving the filament for the present, we will next take up the conductors which carry the current from the outside into the interior of the glass globe. These leading-in wires, as they are called, are imbedded in glass, and it is, therefore, necessary that, when heated, or cooled, they should expand and con-

A GROUP OF LAMP BULB BLOWERS.

tract at the same rate as the latter. They have been made of platinum from the beginning, and though numberless efforts have been made to find an efficient substitute, that metal still holds the field against all comers, as it is the only known substance which satisfactorily fulfills the conditions of infusibility and equal rate of expansion with glass. The earlier lamps had their leading-in wires made entirely of platinum, but as it is one of the precious metals, being worth at present about $10 an ounce, this became too expensive a luxury, and now only that part of the wire actually imbedded in the glass is of platinum. Two pieces of copper compose the rest of each leading-in wire. They are fused at one end and a thin wire of platinum, about a quarter of an inch long, is pressed into the plastic copper, becoming firmly fixed there when the red metal hardens, so that the leading-in wire consists, first, of about half an inch or so of copper sticking into the interior of the globe, then a bit of platinum passing through the glass, and finally, of another length of copper, which is afterward attached to the base of the lamp. This method of procedure reduces the cost of the platinum in each lamp to about one-quarter of a cent, so that it no longer pays to break up the bases of old lamps for the sake of the metal in them.

These composite leading-in wires are then run through a glass tube an inch or two long and about a quarter of an inch in diameter, care being taken to keep the two wires apart and to bring




THE EVOLUTION OF AN INCANDESCENT LAMP.

the platinum section just inside one end of the tube. The latter is then heated and pressed all around the bits of platinum, holding the wires securely in place and forming an air-tight seal. The other end of the tube has previously been widened, like the mouth of a trumpet, so as to be afterward fitted to the neck of the lamp bulb. This tube forms what is called the inside part of the lamp. The carbon filament for the smaller lamps is fastened to the pieces of copper projecting beyond the glass seal simply by means of a certain black paste, which forms a good and lasting binding material. For lamps requiring a heavier current, however, the filament is next grasped at the ends in two metal clamps, and two other metal clamps grasp it about ¼ inch above the ends. The filament and clamps are then inserted in oil, and a current is passed through the short portion of the filament, between the two clamps. The wire to which the filament is to be attached is placed about the filament

between the clamps, and held in this position during the operation. The heated filament decomposes the oil and deposits carbon from the oil upon the short end of the filament between the clamps, and also upon the wires which are placed about the filament, thus embedding both filament and wires in a solid mass of very hard carbon, making a perfect joint.

Let us turn our attention now to the glass bulb which is to enclose the several parts. These bulbs, as well as the tubing, are made in great quantities at regular glass works and form part of the raw material of the lamp manufacturer. They are pear-shaped, or like small flasks, and the first operation which they undergo in the lamp maker's hands is "tubulation." Tubulation is begun by heating the central point of the bottom of the flask with a thin gas flame, and when the glass becomes soft enough, a small tube is inserted in the bottom, so as to open up communication with the interior of the bulb. The part of the tube close to the flask is then drawn out very fine, so that it can be easily sealed off after the air has been exhausted from the lamp.

After having been "tubulated," the bulb is ready to receive the inside part with the attached leading-in wires and filament, and the two pieces are joined by fusing the enlarged end of the inside part to what corresponds to the neck of the flask. This surrounds the interior of the lamp with a complete glass envelope, having no leaky joints. The only communication left with the outer air is through the small, thin tube attached to what was the bottom of the flask, but what has become the top of the lamp, and the latter is now ready to be exhausted.

The air-pump generally used is of the Sprengel type, in which a stream of mercury flows down a glass pipe continuously in one direction. A great many of these pipes are fastened to a rack, and one lamp is connected by means of its small tube, a bit of rubber tubing and a slightly-inclined glass tube with each pipe. The falling mercury

BY KIND PERMISSION OF W J. JENKS.

READING BY THE LIGHT OF THE FIRST LAMPS AT EDISON'S LABORATORY.

THE MAIN ROOM OF A LAMP FACTORY.

carries the air of the lamp with it, and the air bubbles in the moving metallic column become smaller and smaller, finally ceasing altogether. The vertical glass pipes all empty into an iron pipe slightly inclined from the horizontal, and the mercury runs to a pump which lifts it to another horizontal pipe above and opening into the vertical glass ones, and so the flow goes on forever—or rather, as long as the pump-man sees fit. A good absorbent of moisture, such as calcium chloride or phosphoric anhydride, is placed in a small pocket in the glass tubing near the lamp, so as to thoroughly dry the interior.

When the exhaustion is nearly complete an electric current is passed through the filament, heating the whole lamp, and driving out any gases which may have been absorbed by the solid parts; the flow of mercury is continued a little longer, and, at the end, the current is increased and the lamp driven far above normal candle-power for a few seconds. This tests the filament and the vacuum at the same time, and if everything goes well, the lamp is "sealed off" by melting the very narrow portion of its small glass tube, so that it closes up and leaves only a little knob on top of the bulb. This operation is performed with a gas flame, and the lamp is now ready to be attached to its base.

The latter consists, essentially, of two pieces of brass, held in place, and insulated from each other, by plaster of Paris. One of these pieces is usually a thin ring about three-quarters of an inch in diameter and about as wide, with a screw thread on it, and the other is a flat cap about a third of an inch in diameter, centrally placed, so that it projects a little below the bottom of the ring. These two pieces are held in position while the space inside the ring is filled with plaster of Paris. The neck of the lamp is then simply pressed into the plaster, and when the latter has set, one leading-in wire is soldered to the screw ring and the other to the cap, and the actual making of the lamp is finished.

Before leaving the factory each lamp is tested to determine how much current is necessary to bring it to normal candle-power. This test is usually made before the base is attached. The

lamp is hung at one end of a photometer bar and balanced against a standard lamp, which is itself carefully tested every few hours. The electromotive force is then altered until the proper candle-power is reached, when the voltage is read, and the current passing through the filament determined at the same time. The number of volts and number of ampères are etched on the glass, and the lamp is prepared to take its proper place in the world. Various sockets, with keys and without, are employed to hold the base of the lamp and to bring the wires carrying current in contact with the screw and cap, but they do not properly form part of the lamp itself.

FIXING THE LAMP BULBS IN THEIR SOCKETS.

Lamps are made of all sizes, from 100 candle-power and over down to ½ candle-power, but the small ones are decidedly the most interesting and picturesque. At the large factory of which we have spoken, there is a special department devoted to decorative and miniature lamps, of all shapes and colors, curious and beautiful. There are "candelabra" lamps, much used for lighting private residences, and which are generally of 10 candle-power. Some of them are pear-shaped, while others are long and tapering and of an extremely graceful form. They are often fitted to receptacles concealed in imitation candles, and while they have all the warmth and elegance of the old-fashioned wax tapers, they give a far steadier and brighter light. One of the most striking styles is the "flame" lamp, which is a narrow cone of glass, twisted spirally and frosted; it has the beauties of a brightly burning flame, with none of the drawbacks.

There is the 8 candle-power "kinetoscope" lamp, which illuminates the photographs on the rapidly moving celluloid strip in Edison's remarkable picture gallery. A one candle-power lamp is used for night work in telephone exchanges. One is placed in each panel of the switch-board and lights up whenever a call comes to its territory, and stays lighted until the call is answered, so that one or two operators can easily manage all the night business wherever it is not very heavy.

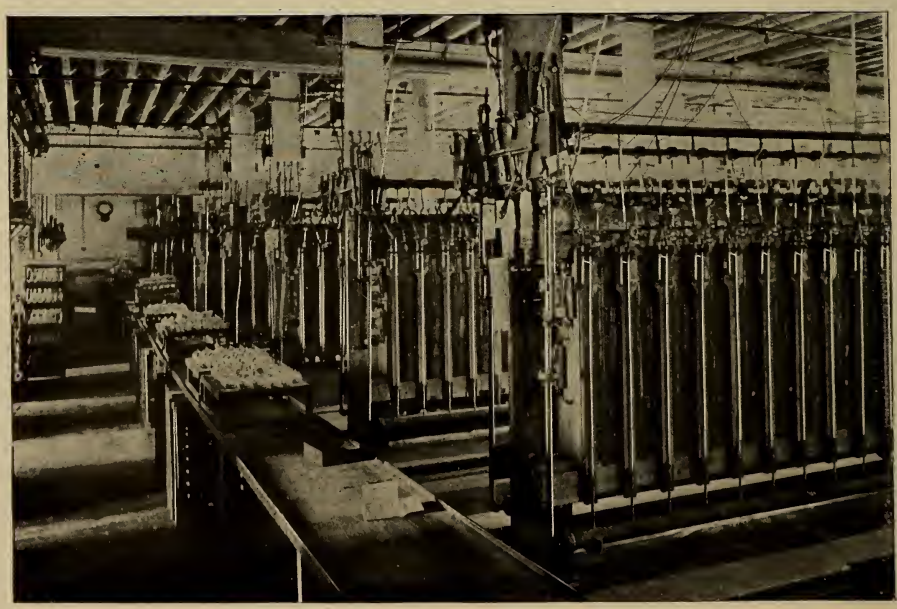
Many varieties of lamps are arranged to take their current from batteries. Among these is the one candle-power miner's lamp, of a flat shape, with metal loops at top and bottom, so that it can be hooked upon springs in the miner's lantern and held steady. The lamp and battery together are not heavy. Then there are bicycle lamps, microscope lamps, and lamps for medical and dental work. Some of the lamps used for illuminating the interior of the mouth, throat and nose, are extremely small, generally cylindrical in shape, a quarter-inch or less in

diameter, and from half an inch to an inch long. But the tiniest of all is the "pea" lamp, a glass sphere one-quarter of an inch in diameter.

Incandescent lamps are very much used for signs and advertising devices of all kinds, and one of the most ingenious arrangements of this kind is the "universal sign," on which the letters can be changed with the greatest ease, and any desirable combination made. Two copper conductors, a positive and a negative, are run the entire length of the sign. The electromotive force between them is sufficient to operate eight one candle-power lamps in series, so that the letters are made up of sets of eight lamps. In order to burn at proper candle-power, the number of lamps in each letter must be eight or some multiple thereof, and the terminals of each set make contact, through flexible metal strips, with the positive and negative conductors as the letters are pushed into place.

The ease with which the incandescent lamp can be controlled, its comparative coolness and its ready adaptability to any position have been taken advantage of to produce many striking and beautiful decorative effects. There are great artificial wreaths and bouquets, with little lamps half hidden among the leaves and flowers. Then there are spirals and curiously intricate patterns made of many colored lamps, which are controlled by revolving switches connected to electric motors, and as the different sets of lamps are cut in and out, the most brilliant kaleidoscopic effects are shown. Clock faces, with shining figures, and wind-mills, with fiery arms, are to be seen, while perhaps most striking of all is a large American flag, on which the lamps are so arranged that as the controlling switch revolves, vertical lines of light and shade chase each other rapidly from end to end of the field, and the Stars and Stripes wave proudly in the breeze.

Some idea of the magnitude of the incandescent lamp industry may be gathered from the fact that the principal factory in the business in the United States turns out, on an average, about twenty-five thousand lamps a day, and has a capacity of thirty thousand. Ninety per cent. of these are of the ordinary size—sixteen candle-power—and the remaining ten per cent. are princi-



THE PUMP ROOM.

TESTING LAMPS FOR CANDLE-POWER.

pally of smaller size, the larger lamps not cutting a great figure in the art. In the early days of the industry it required six watts to maintain one candle-power of light, and, therefore, making allowances for losses in the dynamo and on the line, one horse-power, which is equal to 746 watts, delivered to the dynamo shaft, could keep only about six sixteen candle-power lamps going. To-day the best lamps consume not more than three watts per candle, and one horse-power will run thirteen or fourteen ordinary lights.

In order to obtain good results with the so-called high economy lamps (3.1 watts per candle-power), it is necessary to maintain a very steady pressure on the lines, since an excess of one or two volts above the normal would shorten their life very decidedly. These lamps are, therefore, generally used only in first-class plants, where the regulation is attended to very closely. Lower economy lamps (3.6 to 4 watts per candle) are employed in other places, as they can stand fluctuations of a couple of volts without great injury, although even they do better when the voltage is kept steady, for excessive pressures always shorten a lamp's life, and a slight falling-off in the potential will cause a very decided drop in candle-power. Lamps are guaranteed to burn for six hundred hours on an average, but their actual life is generally much longer, often running up into thousands of hours.

It is a well-known fact that lamps deteriorate with age through blackening of the globe, increasing resistance of the filament and other causes. It requires more and more power to keep them up to normal brilliancy, or, if the same pressure is maintained at their terminals, their light falls off, until at last a time comes when it is economical to put them aside and buy new lamps. This period in the life of a lamp is sometimes called the "smashing point," and in order to determine it, a comparatively simple rule has been given :—"Calculate for each hour in the life of a lamp the total quantity of light given off by it in candle-power hours from the time the new lamp was first started; similarly, calculate for each hour in the life of the lamp the total cost of this light, that is, the original cost of the lamp added to the cost of all the energy consumed by it from the time the new lamp was first started, up to that particular hour. Now, it is evident that if for each hour in the life of a lamp we divide this total

SORTING AND PACKING LAMPS FOR SHIPMENT.

cost up to that hour by the total quantity of light up to that hour, we shall obtain the average cost of a candle-power of light from the beginning up to that hour. From these final data it can readily be shown at what age this total average cost is the least."

Instead of making these calculations for every hour in the lamp's life, it is sufficiently accurate to do so for every hundred hours, and if the results are then laid down in a curve, it is generally found that the age for which the average cost of a candle-power of light is least lies between 300 and 500 hours. If the lamp is kept in use after that period, the candle-power falls off so that the average cost per unit of light, from the time the lamp was started, increases, and it is then more economical to discard the old lamp and replace it by a new one, than to continue running it. The "smashing point" varies, of course, with changing conditions. The smaller the original price of a lamp, the sooner it will be found economical to replace it, while if the power costs but little, the "smashing point" will be postponed for a long time. If the amount of light furnished is of no importance and it does not matter if a sixteen candle-power lamp runs down to twelve, ten or even fewer candles, then keep it going until it dies a natural death. Practically speaking, a slight diminution in light is less striking than a bill for new lamps, and so the latter need not be renewed as often as theory indicates. A good working rule is to run lamps until the falling-off in their light becomes noticeable, for after that point is reached, we may feel pretty sure that it does not pay to use them.

Although eminently satisfactory in so many respects, the incandescent lamp, when considered as an apparatus for converting electrical energy into light, cannot be called efficient. It has been shown by many experiments, particularly those of Professor Nichols, of Cornell University, that only about five per cent. of the energy supplied to the lamp is converted into light, the other ninety-five per cent. being wasted in heat radiation. The incandescent lamp, it is true, is far superior in this respect to

he candle, the oil lamp and the gas flame, as much less than one per cent. of the radiation from the older artificial illuminants is light, all the rest being useless heat ; still there is a great margin for improvement.

That such improvement is possible has been shown by Professor Langley, who, in some wonderfully delicate experiments with fire-flies, proved that all the radiation from the luminous portions of the insect lies within the limits of the visible spectrum ; that is to say, that it is all light, with no waste heat, and that the light-giving apparatus of the fire-fly has an efficiency of nearly one hundred per cent. More recently, Professor H. Ebert has made experiments with luminous paint excited by electrical oscillations of high frequency, and has found that this "luminescent lamp" was many times more efficient than the best incandescent lamp.

Considering the present methods of electric lighting, it seems that the filament is the only part of the incandescent lamp which can be much improved, and though it is slowly being made better and better, it is hardly likely that there will be any change radical enough to even double its present efficiency. The great advance will probably be made in new directions. One of the most inviting fields for work is that which Nicola Tesla has done so much to open up, where alternating currents of high frequency and high potential produce such startling effects. As, however, these currents cannot be transmitted any distance with economy, if, indeed, they can be transmitted at all, it will be necessary to have some efficient converting apparatus at the point where they are to be used, in order to make them commercially possible. Even then, to be most efficient, the frequency ought to be as rapid as that of light vibrations, and we are still a long way from that.

Perhaps some substance may be discovered which can be excited to a bright phosphorescence by ordinary electrical vibrations. The phosphorescent bodies with which we are, at present, acquainted do not give off enough light, but we may reasonably hope to discover something better.

Just how the advance will go on is hard to say, but we can feel certain that progress will be made, and that in good time we shall approach nearer and nearer the perfect economy of the fire-fly's flame.

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# JOHN FRITZ.

## A Noted Captain of Industry.

*By J. F. Holloway.*

AS a conspicuous example of the change in public opinion, and in the drift of modern thought, may be cited the fact that the men now in the foremost place in the esteem and admiration of an intelligent public, are not, as in the long ago, the diplomats, warriors, poets and statesmen, but rather the men who, in the arts and sciences, and especially as engineers, inventors and artisans, have, by their work, helped forward the material progress of their own country, and have aided as well in bringing civilization with its numerous blessings into a broader diffusion, and have distributed its benefits over a wider circle of the human race.

The wizard of the North, whose works charmed the readers of a past genera-

tion, has been eclipsed by the brighter creations of the wizard of Menlo Park. His captain, Delgetty, who held his sword and right arm for hire in the market, for any cause or prince who wanted him, and could furnish him with rations, has with all his ceremonious pomp and pageantry, retired into the background, and the captains of today are the captains of industry, who, with the swords of the past, beaten into the pruning hooks of the more peaceful present, stand at the head of industrial armies whose labors are not, as in aforetime, directed to the upbuilding of Chinese walls between countries, and to the obstruction or obliteration of the paths that trade and commerce had opened up between nations.

It is the province of the industrial armies of this better period in the world's history, under the direction of the engineer and inventor of this wiser age, to advance, at a rate never before known, those arts, industries, and inventions that have had for their aim the bringing together in closer bonds of interest, companionship and good feeling, the men of all climes. To recount how this has been brought about by the inventions pertaining to the steam engine alone, as illustrated in the locomotive, the huge monsters that animate the floating palaces whose swiftly revolving wheels lash into whitened foam the waters of every known sea, or that rotate the wheels from which thousands of swift flying spindles catch that hum of industry which brings music to many a home ; engines, whose pulsating strokes lift from the lakes and rivers fountains of water for the health and comfort of the citizen, or which, with strange complexity of mechanisms, twist and wrench with a relentless force from out of the hidden recesses of nature, that unseen etheric force which, sent along trellised structures, blossom here and there into arch-lights of dazzling brilliancy, or in remoter recesses, glow in milder incandescence. To the thinking reader will come the thought that if in one single line of industry so much may be said, then to cover all the lines to which engineers and artisans have bent their energies would be a colossal task, too great to be hastily undertaken. It is, however, well to thus review, even ever so briefly, what has been accomplished by the men who, while not recognized in the past as they should have been, are now becoming more prominent in the esteem of all.

Foremost as a worker in a field of industry, the progress of which, in the past fifty years, has been marvelous to a degree, and which, as a factor for good, has no rival, the manufacture of iron and steel, few men, now living, have had a longer or larger experience than has had John Fritz.

Like many another who in this land have earned their promotion in industrial affairs, and have secured the esteem of their fellow men, he was born of humble parentage and grew up under conditions which, while they debarred him from obtaining that technical training now so readily to be had, taught him that sturdy honesty, persevering fidelity and untiring industry, by which he has been able to accomplish so much within the period of his active life.

Mr. Fritz was born on August 21, 1822, in Londonderry Township, Chester county, Pa. He was the oldest of a family that consisted of three brothers and four sisters. His parents lived on a farm and the first sixteen years of his life were spent on that farm. At this early age, influenced by a desire to help himself and his parents, and with a wish to know more of mechanical pursuits, he left home and went to Parksburgh near by to work in a country machine shop, with a view of learning the trade of a machinist. As in all the country shops of that day, the apprentice boy had a varied experience which ranged from cleaning castings and striking in the blacksmith shop, up to the more important position of running a drill press and managing a hand lathe.

While the young men of the present might be inclined to look upon such labor as time wasted, it proved, in this instance, a mine of information and experience, from which, in after years, Mr. Fritz drew much that aided him in the accomplishment of his life work.

From there he went to Norristown, Pa., where there were larger shops and larger opportunities. As an illustration of what were the limitations of even the largest shops of that early day, it was said that in this whole establishment there were only one man and a boy who could properly set the valves of a steam engine. From there he was sent to Safe Harbor, Pa., to put up the machinery of a rolling mill under the direction of the manager, the late John Griffin, whom, together with David Reeves, Mr. Fritz numbered among his warmest, life-long friends, and to whom he was very much indebted for counsel and advice.

As an example of the state of the art of planning and building rolling mills and their machinery when Mr. Fritz was a young man, it is said that at one time he happened to be present when a new rolling mill was about to be started, and which was supposed to be very much in advance of any previously built. When all was ready and steam was turned on the engine, to the surprise of the mill men, the rolls began turning in the opposite direction to that intended, and when the owner discovered the error, with uplifted hands and a despairing look, he came to where Mr. Fritz was standing and exclaimed, "The whole business is wrong, the mill will have to be built over and turned around." "Oh, no," Mr. Fritz said in his quiet way, "Just turn the cams on the engine shaft half way around, and the rolls will go all right."

About this time Mr. Fritz was induced to take charge of the Kunsie (Anthracite) blast furnace, and after remodeling it and putting it in order, ran it for some time, returning later on to Norristown, from where, in 1854, he went to Johnstown to remodel and rebuild what has since been known as the Cambria Iron Works. The story of his connection with that pioneer iron and steel plant was so well told by Mr. Fritz at the recent Bridgeport meeting of the American Institute of Mining Engineers, of which society he now is President, that it is quite unnecessary to allude to it here, except to say that no better lesson has been taught, or example shown to young engineers and artisans, of the value of untiring industry and persistence in following one's convictions when carefully thought out, than was the story there related.

In 1860 several gentlemen, some of whom are not now living, organized a company for the purpose of building a furnace and rolling mill on the banks of the Lehigh river, below the then town of Bethlehem, and the young engineer who had done so much for Cambria, and had invented and shown the great advantage of the three-high roll train over the old method, was selected to plan and build what has since acquired a world-wide reputation, as the Bethlehem Iron Works. The steady growth and success of this plant, and its enlargement to what it now is, comes so close within the knowledge of every one interested in the current events of the day as they pertain to the manufacture of iron and steel in all their various forms, that it does not require an extended notice here.

It was in the early days of the Bethlehem Iron Works, that rumors of the newly discovered process of making steel by blowing air through melted cast iron reached the United States, and, outside of the few persons engaged in the experimental plant at Troy, in New York, there were none who were more interested in the study of the process than John Fritz. When, after long delays and numerous disappointments, the experiments conducted under the supervision of the late Alexander L. Holley had achieved sufficient success to induce the investment of capital to build works on a larger scale, the managers of the Cambria Works made arrangements with Mr. Holley to erect at Johnstown a Bessemer steel plant to be run in connection with their blast furnaces and rolling mill.

At that period George Fritz, a younger brother, had, for some time, been employed under the direction of John Fritz in the construction and operating of the iron mills at Bethlehem, and Mr. Holley, knowing something of his ability, and knowing too of the ex-

cellent training that he had gone through, induced him to go with him and assist in the erection and management of the Cambria Company's plant, where, up to the time of his death, he made a record second to none. Soon after this, the Bethlehem Iron Company determined also to go into the manufacture of steel under the Bessemer patent, with what success is known far and wide.

The history of Mr. Fritz's life at this period would be incomplete were not some mention made of the coterie of young men who circled about, and looked up to him for aid and counsel, and all of whom were active in assisting to develop in the United States this new and as yet incomplete process, and which, later on, was to work such wonderful changes, not only in the United States, but the world over. This group of eight or ten persons might well have been designated as the "Bessemer boys" of '65 and '70. Young, active and daring, they pushed forward inventions, plans and appliances, which, in other countries, and among more conservative people, would have been deemed hazardous, but which, happily, in most instances proved successful, and which did much to advance with rapid strides the production of both iron and steel in the United States.

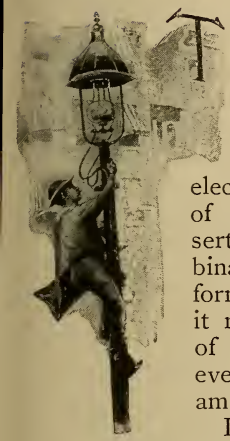
But the ranks of the "Bessemer boys" have been thinned by death. First to go was the prized leader, Alexander L. Holley. Then followed the "daring engineer, alway advancing, ever right, warm, uncompromising friend, George Fritz;" then the two Jones, Daniel N. and William H. Others remain to meet now and then as captains of industry, to talk over the battles fought, and victories won, and, let us hope, to receive the honors and emoluments which they so richly deserve.

Long as is this sketch of Mr. Fritz, it would not be complete were not mention made of the splendid ovation tendered him on the anniversary of his seventieth birthday, when some three hundred of his friends, embracing representatives of the government, noted presidents and professors of colleges, famous engineers and iron and steel makers from all parts of the country, lawyers, clergymen and old neighbors met in the floored-over and tastefully decorated Opera House of Bethlehem to honor him for what he had accomplished as an engineer, and to love and respect him for a life which, busy to a degree, had time in which to be courteous to the most lowly, and to give aid, comfort and sympathy to the unfortunate and poor.

The regard in which Mr. Fritz is held is by no means confined to his own country, for beyond the sea his record is known, his skill acknowledged and his character admired. But a few weeks ago the president of the British Iron and Steel Institute, E. Windsor Richards, came to the United States mainly that he might place in the hands of his warm, personal friend, the token of his Society which, when awarded to any one, is their highest recognition of the engineering skill and honorable and manly character of its recipient, and when John Fritz reached out his hand to receive the Bessemer gold medal, sent him from over the sea, his modesty made him say, "I receive it not so much for what I have done, but for what American engineers and workmen have, by my help, accomplished."

# COMBINED EFFICIENCIES OF MECHANICAL AND ELECTRICAL MACHINES.

*By Edward J. Willis.*



THE law of conservation of energy has a corollary in the modern technical term "efficiency," which takes a most important part in mechanical and electrical engineering. The law of conservation of energy asserts that no machine or combination can ever deliver in any form or forms more energy than it receives, and that the amount of energy distributed must, in every case, exactly equal the amount received.

Let us apply this to a railroad train. The train receives heat energy, stored up in the coal which it takes upon its tender. The coal is burnt, thus turning into heat its latent energy of chemical combination. A portion of this heat passes out of the smokestack, and the remainder, approximately speaking, is imparted to the water which it turns to steam. The steam goes to the cylinders, delivers part of its energy to the pistons, and then passes out through the exhaust pipe, carrying with it nearly all that portion of its energy which it has not delivered to the pistons. The energy of the pistons is communicated to the wheels of the engine and, pulling the train, is lost in overcoming the resistance of the air and the friction of tracks and bearings. The train gains speed, thereby increasing these last mentioned frictional losses until the total energy expended exactly equals that received from the burning coal.

If we knew how all the losses were related to each other, and also their relation to the speed of the train, we could form an equation and solve for speed; or assuming speed, solve for the amount of coal the engine would have to burn to run at the speed assumed. In the case of the locomotive this would be hardly possible, but in the case of other prime movers, the relations of these losses of energy are much more exactly known, and afford an excellent method for both the calculation and for the comparison of different designs.

A simple case is that of a water-wheel. Suppose we had a stream passing 44 cubic feet of water per second and falling 20 feet. This would represent $3\frac{1}{3}$ million foot-pounds of energy per minute. Suppose that in order to make use of this water-power we were to put in an old-fashioned overshot wheel which, we know, would waste about one-third of the energy, and turn the other two-thirds into work. This would give us about 66 horse-power for use. If, instead of the overshot, we were to put in a good turbine which would not waste over 15 per cent., we would get 85 horse-power instead of 66. It is, therefore, simply a matter of calculation whether the 19 horse-power increase is worth the difference in the cost of the wheels.

The steam engine offers a more complicated example, as it involves a series of losses. A good boiler should certainly not waste over two-fifths of the heat of the fuel, and the remaining three-fifths should pass over with the steam to the engine. A fairly good engine will waste from 93 to 94 per cent. of the energy of the steam that it receives, and converts the remaining 6 or 7 per cent. into useful work. Engines are not rare which waste 95 per cent. Even the very latest types of modern compound condensing engines do not, in actual practice, usually exceed 10

per cent. of the energy of the steam converted into useful work. Since, then, a fairly good boiler sends only about 60 per cent. of the energy of the coal to the engine, and a fairly good engine utilizes only about 6½ per cent. of this 60 per cent., we have it that an ordinary engine and boiler convert only about 4 per cent. of the energy of the coal into useful work, and wastes the remaining 96 per cent.

Suppose that instead of this fairly good boiler we had put in the best that we could get, which might waste only about one-fifth of the heat of the coal, that is, would impart 80 per cent. of the energy of the coal to the steam; also, that instead of the fairly good engine, we had put in an expensive, compound condensing engine which might have utilized 10 per cent. of the energy of the steam that it received. We would then utilize 10 per cent. of 80 per cent., or 8 per cent. of the energy of the coal. It is, again, simply a question of calculation whether the 4 per cent. saved is worth the increased outlay necessary to put in the better machinery.

Let us go still further, and suppose that this first-class boiler and compound condensing engine, with a net efficiency of 8 per cent., ran a dynamo supplying current for incandescent electric lights. If the dynamo were a good one and properly loaded, it should deliver, in the form of electric current, 85 per cent. of the energy received by it, that is, 85 per cent. of the 8 per cent. above mentioned, giving, in the form of electricity, $6\frac{8}{10}$ per cent. of the energy of the coal. As the line would lose from 2 to 5 per cent. of this, the amount received by the lamps would be reduced to about 6½ per cent. It has been established by laboratory experiment that under most favorable conditions an incandescent lamp uses about 9 per cent. of the energy received by it for light, the remaining 91 per cent. being lost in the form of heat. Since, as stated above, only 6½ per cent. of the energy of the coal reaches the lamp, only 9 per cent. of the 6½ per cent., equal to about $\frac{6}{10}$ of 1 per cent., is used for light. In other words, in the best incandescent electric light plant only $\frac{6}{10}$ of 1 per cent. of the energy of the fuel burned is utilized for light, and $99\frac{4}{10}$ per cent. is wasted in not only useless, but in detrimental, effects. In the usual run of electric light plants the result is not so good as this, but rather tends toward average figures, not exceeding 6 per cent. for the engine and boiler, and about 6 for the lamps, or allowing 15 per cent. loss at the dynamo, a net efficiency of about $\frac{3}{10}$ of 1 per cent.

Lights, like the steam engine, are very inefficient. A candle has an efficiency of about $\frac{3}{10}$ of 1 per cent. A kerosene lamp has an efficiency which varies, depending greatly on the kind of wick and burner and grade of oil used. Approximately, a good lamp might be said to have an efficiency of about $\frac{6}{10}$ of 1 per cent.; that is to say, a kerosene lamp gives out $99\frac{4}{10}$ per cent. of the energy of the oil which it burns as heat, and the remaining $\frac{6}{10}$ of 1 per cent. as light.

An ordinary gas burner has an efficiency of about $\frac{7}{10}$ of 1 per cent., but as not all the energy of the fuel used at the gas works goes into the gas, the efficiency of a gas plant is not as high as this. In good water gas plants it is not unusual to get a little over 60 per cent. of the energy of the fuel burnt at the works into the gas, and this would give a net efficiency of about $\frac{43}{100}$ of 1 per cent. It might be assumed that ordinary good practice would give a net efficiency of about $\frac{4}{10}$ of 1 per cent. A comparison of the efficiencies of these most frequent methods of house lighting is interesting on account of the fact that it will, to a certain extent, indicate their relative economy. The candle, with its low efficiency of about $\frac{2}{10}$ of 1 per cent., and consuming an article very costly compared with coal and kerosene, is, of course, the most expensive. Next comes the incandescent electric light with a net efficiency of $\frac{3}{10}$ of 1 per cent.; next, the ordinary gas burner with a net efficiency of about $\frac{4}{10}$ of 1 per cent., and ahead of all the others, both in efficiency as well as sim-

plicity, comes the ordinary kerosene lamp. All know how with the poorer classes, where expense is the chief issue, kerosene is the victorious rival of both gas and electricity. Gas is more convenient and more expensive than kerosene, and the incandescent light is more convenient and more expensive than gas. While electricity, in point of efficiency, appears but little behind gas, still it must be remembered that it involves a more expensive plant, as well as the use of more skilled and expensive labor. In point of convenience, health, comfort and safety, the incandescent light is the best, gas comes next, and kerosene last. The user must decide whether the advantages in his special case are worth the greater cost.

Except in the rare instances where water power is used for electric lighting, the above comparison of gas and electricity appears correct. Where water power is used, it is quite possible for the incandescent light to be the cheaper. The lights compared here are not the most efficient known, but were selected as the usual ones employed at the present time. The arc light, while for various reasons unsuited for house illumination, is probably the most efficient light known, as it can convert over half the energy which it receives into light. It is probable that in ordinary practice its efficiency is as high as 35 per cent. Supposing it to be run by an ordinary steam plant, with an efficiency of about 6 per cent., we would have a net efficiency of $2\frac{1}{10}$ per cent. As this is so far above our former figures, we can see why the arc light can, for outdoor illumination, favorably compete with gas and oil. While electricity has, in the arc light, attained, for outdoor illumination, the high figure of $2\frac{1}{10}$ per cent., gas has also nearly reached the same figure for indoor lighting in the burner of Dr. Von Welsbach, which will give 20 candles per cubic feet of gas, or a net efficiency of about $1\frac{3}{4}$ per cent. Various causes have retarded the general introduction of this very efficient burner, but it is to be hoped for many reasons that this soft, steady light will replace the smoky and flickering flame of the ordinary gas burner. For outdoor lighting, it is not unusual for gas when burned in the Siemens–Lungren type of burner to reach a net efficiency as high as $\frac{8}{10}$ of 1 per cent.

The inclination of the present day to adapt electricity to all and any purpose, leads sometimes to bad economy. Prominently in this connection comes the electric stove or heater. It has been shown in a preceding paragraph that the net efficiency of an ordinary electric plant is about 6 per cent., or, in other words, not over 6 per cent. of the energy of the coal is turned into electricity. If this electric current, representing 6 per cent. of the energy of the coal, were used to run an electric heater, the latter would turn practically all this electricity into heat, and we would have 94 per cent. of the heat of the coal lost in waste at the boiler, engine and dynamo, and only 6 per cent. used for heating the room. An ordinary stove with a long stove pipe does not waste probably over 45 per cent. up the chimney, and the remaining 55 per cent. is used to heat the room. If, therefore, we were to heat the same room, first, by a stove, and then by electric heat, all conditions being the same, we would find that the electric heater would take about nine times as much coal as the stove, besides involving the use of engine, boiler, dynamo and skilled labor.

A comparison of the efficiencies of the boiler, engine and dynamo, gives some information concerning the advance possible with these important factors of modern engineering. As a good boiler wastes only from 20 to 25 per cent. of the heat of the fuel, it is easy to see that if a man were to invent a boiler which was perfect—that is, which gave all the heat of the fuel to the water—it would do only about one-quarter better than those now built, or, in other words, the perfect boiler would cut the coal bill down only one-fifth. The engine, however, fails to utilize $\frac{9}{10}$ of the energy of the steam, and an engine which turned all the energy of the

steam that it used into work would, therefore, do ten times as much work as the best modern engines. In other words, it would reduce the coal consumption to $\frac{1}{3}$ its former figure.

Modern electrical machines are, like the boilers, so nearly perfect that there is not room for radical advance. A good dynamo or motor should, if properly loaded, have an efficiency of about 80 per cent., and a perfect one would, like the boiler, make a saving of only one-fifth in fuel. It is, however, easy to see that a small rise in the efficiency of the steam engine represents a great improvement. If a new steam engine had an efficiency ten points better than those now made, it would have an efficiency of 20 per cent. instead of 10 per cent., and would do twice the work with the same amount of steam.

The low efficiency of the steam engine has attracted the attention of inventors, and many useless patents are proofs thereto. As the latent heat which disappears when water is turned to steam is a source of a great deal of the loss, other gases have been proposed as substitutes. The most prominent of these is air. An air engine is, if properly made, more efficient than a steam engine. Ericsson's large engine reached as high a figure as 25 per cent., or two and a-half times that of the best steam engine. Air engines are, however, very large and expensive for the amount of work that they can do and, besides, have many points which cause them to be far less reliable than a steam engine. They are, in practice, limited to small horse-powers, where unfortunately the question of efficiency is not so important. The ordinary gas engine can be, with proper construction and under favorable conditions, more efficient than the best steam engines, reaching, sometimes, results as high as 20 per cent. of the heat of the gas converted into work. They are not as large for their power as the air engine, but, still, are much larger than the steam engine.

The often talked-of time when the electric motor will supersede the steam engine does not deserve serious consideration, as certainly at the present time, and probably for some time in the future, the motor will only aid and extend the introduction of the steam engine by giving a wider field for the application of the power which is generated by the engine. Except in the rare instances where water power is used to generate the current which runs a motor, the latter never comes in competition with the steam engine, as there must be an engine somewhere to run the dynamo which supplies the current.

The use of an electric motor involves two transformations of energy, the first at the power house by the dynamo, transforming the energy of the engine into electricity, and the second at the other end of the line by the motor, transforming into work the energy of the current which it receives. Each of these transformations involves a loss of power of from 15 to 40 per cent., so that the net loss necessitated by the introduction of a motor is from 25 to 50 per cent. This loss has to be made up by delivering more power to the dynamo than is needed by the motor to perform its work. The consequence is that a larger engine has to be used at the power house than would be necessary if the engine were established directly in the place of the motor. Thus not only does the motor tend to increase the introduction of the steam engine by widening its field of utility, but further necessitates the use of larger engines than would be the case if the motor were not employed.

## Current Topics.

It is not so long ago that a 50 or a 75-horse-power gas engine was one of the big things in engineering, and was looked upon as a noteworthy achievement. How completely this state of affairs has been changed is perhaps best shown by the several recently-published accounts of the power plant of the Pantin flour mill in France, which comprises a single-cylinder Simplex gas engine, rated at nothing less than 320 indicated horse-power. The brake horse-power is 250. The engine is worked by producer gas, and has been pointed to as an admirable illustration of the certainty with which the steam engine is being displaced for various kinds of work, though slowly, perhaps, by other forms of motors. Now that this jump to a 320-horse-power gas engine has been made, and, apparently, with results of a most encouraging nature, an early step to still larger sizes seems more than probable, and it may not be long before we shall hear of the building of the 500-horse-power engine which Messrs. Matter & Co., of Rouen, the builders of the present Simplex engine, are holding in view. Messrs. Thwaite and Swinburne, in England, too, in agitating the subject of distributing electricity from the Midland coal districts direct to London, have contemplated the use of gas engine units of 300-horse-power for a 10,000-horse-power station, so that the era of gas engines of several hundred horse-power each would seem to be fairly ushered in. The Pantin mills engine has a 34½-inch cylinder, with a length of stroke of a little over 39 inches, and, as a result of a 194-hour test, showed a consumption of 1.043 lbs. of coal per brake horse-power per hour. The consumption of jacket cooling water and water for the gas-producers and washer for the same test was found to be 58.3 lbs. per horse-power per hour, or very much less than the best condensing steam engines would use, though about double the quantity that would be required for the best non-condensing engines. In many cases, however, the cost of water would be little or nothing. Later tests confirmed these results, which certainly ought to make their influence felt in the more rapid introduction of cheap gas systems and still further improvement in the design of gas-producers.

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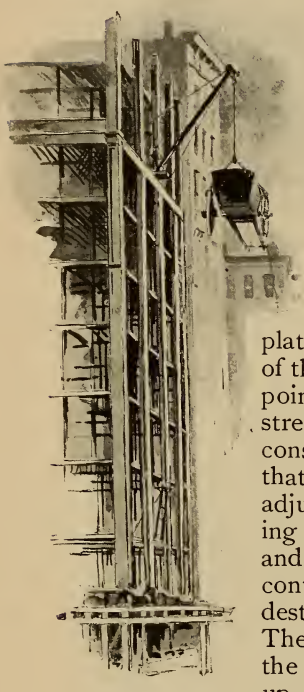
To what extent economy in the handling of materials can be carried is shown very well by the annexed little sketch, which illustrates the practice of

at least one tall office building contractor. Rather than raise in small quantities the coke needed for the steam derrick outfit on the upper level of the rising building, he hoists the cart, contents and all, in one lump from the street below, dumps the fuel up above, where needed, and again lowers the cart to be hauled off for another load. There is no filling and emptying of barrows, no wheeling of the latter to and from hoisting platforms, no handling of the coke between the point of delivery in the street and the point of consumption, except that involved in the adjustment of the hoisting slings to the cart and the dumping of the contents when the final destination is reached. The horse is unhitched, the full cart sails merrily up aloft and returns empty. We have here what might be called a direct process with all unnecessary intermediaries eliminated. It is just such practices as this one which help to swell the list of small economies and produce bigger profits than fall to the lot of the man less ready to avail himself of low-cost expedients.



A SHORT CUT.

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GREAT speed, moderately thick armor, and numerous quick-firing guns are the requirements of the ideal fighting ship, viewed from the standpoint of Laird Clowes, who has become known as one of the ablest English authorities on naval matters. What he would have is a 101-gun ship, of which he has drawn the following picture: "A ship of from 10,000 to 12,000 tons displacement, carrying 6-inch steel armor all over her, steaming 22 or 23 knots, and mounting some such armament as sixteen 6-inch guns, twenty 4.7-inch guns, twenty 3-inch 12-pound guns, twenty 6-pound guns, all quick-firers, with twenty-five Maxims of a caliber some what larger than the one in present service use. Then we should have a 101-gun ship, against which no man-of-war in existence could stand up, and from which no man-of-war in existence could escape."

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NOT a little guesswork has been gone through by many as to the probable quantities of coal which are daily shoveled into the furnace mouths of such big Atlantic liners as the steamers Paris, New York, Campania and Lucania. Ten years ago one hundred tons a day were considered a most prodigious consumption, little likely to be exceeded in the years to come, and wondering comment there was in plenty that so vast a quantity should find a legitimate use. Since then, however, the public mind has been educated up to higher figures, and statements of two and even three hundred tons a day have ceased to attract more than passing notice. Three hundred and fifty tons, in fact, are said to be burned on the Paris and the New York in every twenty-four hours, but of the Lucania and Campania no particulars have ever been given, so that an approximation, based on what is known of the power equipment of these ships, is all that can be offered. Twenty-eight thousand horse-power has been assumed to be the amount that each of these vessels require to propel them at the great speeds which they maintain. Added to this power of the main engines must be the appreciable figure represented by the host of auxiliary engines and pumps which are necessary adjuncts, and which, with the steam-heating systems and hot water apparatus, help to swell the steam consumption to such a degree that a total allowance of, say, sixteen pounds of steam per hour for each of the twenty-eight thousand horse-powers may be

taken as quite within the mark. Allowing then, too, a boiler performance of eight pounds of steam per pound of coal, which cannot be far wrong, we have a coal consumption of two pounds per hour for each horse-power, or 56,000 lbs., equivalent to 600 tons per day. This is pretty plain figuring, though, of course, partly speculative, and while the outcome may seem exaggeratedly high, it, no doubt, quite truthfully represents the facts in the case.

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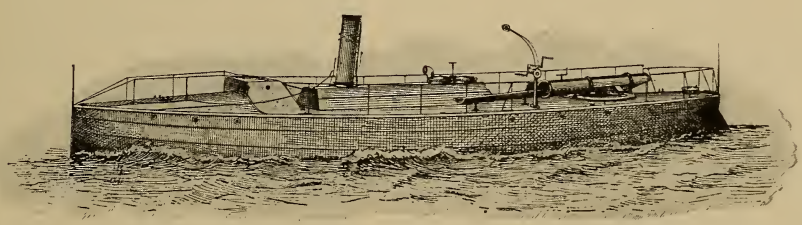
THE fact brought out by some recently completed tests, made by the United States Navy Department, that aluminium is not suitable for boats, because of its great susceptibility to the corrosive action of salt water, is indeed a disappointing one. Much has been hoped for from this metal on account of its great lightness and strength, and as a structural material for boats particularly it seemed to promise well and to open up possibilities of a most alluring kind. Now, however, that it has apparently been shown to succumb rapidly to the attacks of sea water, some of the elaborate claims which have been made for it are practically demolished. In the tests referred to, which were made at the Norfolk Navy Yard, in Virginia, two sheets of metal, one-sixteenth of an inch thick, had been immersed for a period of three months. One was of pure aluminium and the other was slightly alloyed with nickel. The pure plate was thickly covered with large barnacles over its entire surface, and was more or less pitted by the action of the salt water. The alloyed plate was incrusted with smaller barnacles and was badly corroded, being perforated and eaten away over much of its exposed surface. This plate was as injuriously affected as a combination of iron and copper would have been with the same exposure. The claim that barnacles would not adhere to the metal was not substantiated in the smallest degree. In the opinion of naval experts, therefore, it will not be advisable to build aluminium boats if they are intended to remain any length of time in the water, though the use of the metal may be advantageous on account of lightness for metal work exposed to salt water only occasionally; in fact, the use of aluminium near salt water cannot be recommended under any circumstances. In view of these conclusions in the United States, it is all the more interesting to note that the results upon which they were based were by no means borne out by somewhat similar tests made by the French naval authorities within the past year. No appreciable corrosion was shown by these, and on the strength of this experience Messrs. Yarrow & Co., the well-known English builders, were given an order for a second-class aluminium torpedo boat, which now forms part of the French navy. The boat is about 60 feet long, 9 feet 3 inches beam, draws a little over 3 feet of water and has a maximum displacement, with everything on board, of 14 tons. It now remains to be seen whether with the boat itself, rather than with test plates only, any new and important discoveries will be made. The aluminium test plates in the French experiments were attached to the coppered bottom of a sailing vessel, and were examined just before



A SECOND CLASS ALUMINIUM TORPEDO BOAT, BUILT BY YARROW & CO. FOR THE FRENCH NAVY.

and after a long cruise, and it is not impossible, therefore, that their stated immunity from corrosion may be traced to some electro-chemical action set up between the two metals.

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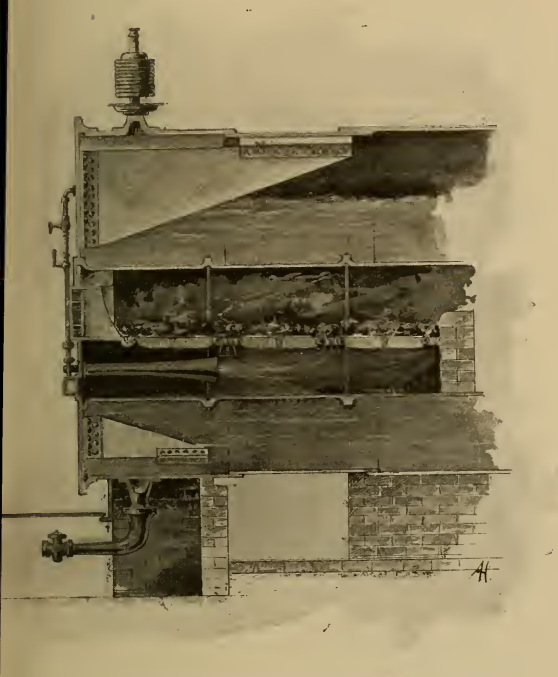
SUGGESTIONS for novel uses for the electric incandescent lamp, other than as a light-giving agent, have been made at intervals almost from the first appearance of the commercially successful lamp, among them, for example, that of employing it as a warming pan, in which capacity, however, it has probably not found much application. But

A NOVEL ELECTRIC HEATER.

more recently, the lamp, as a heater, has again attracted notice, and one of the latest adaptations of it as such is shown in the appended little sketch which fully explains itself. The lamps, in sizes of 8, 16 and 50-candle-power, are used for heating tea and coffee pots, and seem to have very satisfactorily demonstrated their value in this new field. A 50-candle-power lamp will, it is said, raise from two to three pints of water of average temperature to the boiling point in about twenty-five minutes ; a 16-candle-power lamp will keep the water at the boiling point, and an 8-candle lamp will keep water sufficiently hot for afternoon tea.

WITH the increasing need of forced draft systems for burning some of the lower grades of fuel in steam boiler furnaces, special attention is centered in what is now being accomplished in this field. Not the least interesting of the several forced draft appliances which have been put to successful use is that of Messrs. Meldrum Brothers, of the Atlantic Works, at Manchester, England, who, for a number of years, have given much study to the subject, and whose system, as illustrated in the accompanying sketch, is now doing good work in many places. The use of the blast permits, of course, of maintaining the rate of combustion at a much higher rate per square foot of grate than is possible with natural draught, and it is in this point that the success of the practical application of the system mainly lies, since diminished calorific value of the fuel can in the majority of cases be more than atoned for by its increased rate of combustion, so that the same boiler is enabled to do the same amount of work. Thus, the adoption of the system does not necessitate increased space or increased capital for boiler plant. Indeed, in some cases the adoption of the system has permitted of one or two boilers in a range to be laid off in consequence of the extra duty that was obtained from the others. Just what the Meldrum system is, the sketch tells quite plainly, representing the arrangement adopted with an ordinary Lancashire boiler. Air is delivered under pressure into the closed ashpit by means of a steam jet blower, and without necessitating any interference with the regular hand-firing arrangement. The steam for the blast is taken from the boiler itself, and the whole outfit is about as simple as one could desire it, resembling, in some respects, the steam jet blowers which have, for years past, been used with such good results in the Pennsylvania coal regions in the United States, where the practice of burning culm for steam raising has assumed extensive proportions. It is not, however, to steam boilers alone that this system of firing is necessarily confined. The Meldrum

blast, in fact, has been applied to almost every class of furnace used in manufacturing industries, including gas re-



THE MELDRUM FORCED DRAFT SYSTEM.

torts and puddling furnaces, and in all cases, it would appear, uniformly good results have been achieved.

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To produce light without heat, and, consequently, with the expenditure of extremely little energy, has been the object of a prodigious amount of experimenting, and some rather startling results have been attained through the medium of vacuum tubes with the aid of electric alternating currents of high frequency. The latest of these were recently detailed in Wiedemann's Annalen by Professor H. Ebert, who, in determining the efficiency of what he called his "luminescent lamp," having a candle-power equal to from one-thirtieth to one-fortieth of that of a standard English candle, found the energy actually expended to be only about one-millionth of a watt, giving an efficiency many hundred times that of the now-used incandescent lamp. The possibilities opened up by Professor Ebert's investigations are interesting to contemplate, the more so as they have been confirmed independently by more than one other worker in the same field. "Cold light," indeed, would seem to be one of the promises of the not very distant future.

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One of the several interesting things that M. Raoul Pictet, of ice machine fame, has lately made public is the account of what he calls "cold burns," — burns produced by the extremely low temperatures with which he has been experimenting. There are two degrees of burns. In one case the skin reddens at first and turns blue on the following day, and subsequently the area of the spot expands until it becomes nearly double its original dimensions. The burn, which is usually not healed until five or six weeks after its occurrence, is accompanied by a very painful itching on the affected spot and the surrounding tissues. When the burning is more serious, produced by longer contact with the cold body, a burn of the second degree is experienced. In this case the skin is rapidly detached, and all parts reached by the cold behave like foreign bodies. A long and stubborn suppuration sets in, which does not seem to accelerate the reconstitution of the tissues. The wounds are malignant, and scar very slowly, in a manner entirely different from burns produced by fire. On one occasion, when M. Pictet was suffering from a severe burn, due to a drop of liquid air, he accidentally scorched the same hand very seriously. The scorched portion was healed in ten or twelve days, but the wound produced by the cold burn was open for upwards of six months.

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Peculiar causes of destructive fires have formed the subjects of many interesting little paragraphs, one of which, now going the rounds, is to the effect that in at least two cases such fires have been started by water. In

one of these a flood caused the water to rise high enough in a factory to reach a pile of iron filings. These, on coming in contact with the water, oxidized so rapidly that they became intensely heated, and then set fire to the neighboring woodwork, and the building was destroyed. In the other case, the water from the engines, during a fire, found its way into a shed containing quicklime, and the heat generated by the slaking of the lime set fire to the shed, and this to other buildings. Quicklime fires, however, are not uncommon. Many vessels carrying quicklime have probably been burned by the admission of water to the lime through a trifling leak, and no architect or builder need be told how intense the heat of slaking lime may be. Glass globes, which act as lenses, too, may start fires, and it has been claimed by some that the convex glasses used in sidewalk lights are dangerous, and should be abandoned in favor of lights with flat tops.

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GETTING more heat out of a pound of coal than is in it is one of the interesting things which seems to have been accomplished so often by inventors of new-fangled steam boilers, that it has ceased to be surprising. Occasionally, however, rather startling boiler performances are reported from more trustworthy sources, and for some time, therefore, there has been a growing suspicion in the minds of many engineers that the long-accepted figures for the heating values of different coals were not all that was claimed for them and might well bear revision. Calorimeter tests of coals, as ordinarily carried out with small portions of the fuel, burnt under special conditions, not always favorable to the attainment of the best results, are, after all, simply laboratory experiments made with all their artificial surroundings, and it was scarcely to be expected that their results would stand unquestioned for any great length of time. What really has been needed all along is a convenient means of testing for the heating value of a coal under actual practical conditions, such as are met with in every-day boiler practice, burning large quantities of the fuel and thus reducing the percentages of error to the lowest possible notch.

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IT is all the more interesting, therefore, to note that at Pribram, in Austria, there exists such a fuel-testing station, maintained by the government, and intended to carry out trials on a practical scale for any person desiring them. To completely carry out a test, 10 tons of the coal or other fuel are to be sent to the station. This quantity is divided into two lots of 5 tons each, and a separate test is carried out on each lot, the results thus obtained checking each other. The tests are carried on continuously, day and night, until completed. An analysis is also made of an average sample of the fuel, as to its chemical and physical properties, which are set forth in the certificate issued, giving the results of the trial. The charge for carrying out a test of this kind has been fixed at about £8, or $40, truly a moderate enough figure, including also the chemical analysis of the fuel. Unless the parties interested object to it, the results of the tests are to be published from time to time.

Carnot

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## A TWELVE-MILE TRANSMISSION OF POWER BY ELECTRICITY.

*By Thomas H. Leggett, Mem. Am. Inst. M. E.*

THE POLE LINE IN A 15-FOOT SNOW DRIFT.

THE value of electricity as a tonic has long been recognized by the medical profession, more especially its revivifying effect in nervous and allied troubles, in which field it has accomplished many remarkable cures. The miner is but beginning to realize that it may exert an equally beneficent influence in his sphere of work, and more than one apparently exhausted mining camp, tottering on the borders of decay, has been rejuvenated by its introduction, and given a new lease of life through the economies following upon its use. Special interest is, therefore, attached to the following description of one of the most extended electric transmissions of power now in operation in the United States, the matter having, in part, previously been given in a paper read by the author before the American Institute of Mining Engineers.

At Bodie, California, the ruling price for wood has been, for years past, $10 per cord, so that the monthly fuel-bills of a 20-stamp mill, crushing and amalgamating 50 tons of ore per day, would often amount to $2000. To reduce this excessive cost of motive power was the problem in hand, and the use of electricity generated by water-power has solved it. No sufficient water-power could be found nearer than 12½ miles

THOMAS H. LEGGETT graduated as Engineer of Mines at the Columbia School of Mines at New York in 1879 and has been in practice as mining engineer and manager of properties ever since, operating in the western part of the United States, in Mexico, and in Central and South America. At present he has an office at San Francisco, Cal., and is president and manager of the Standard Consolidated Mining Company, with mines at Bodie, in the same State. In this position, and with the introduction of electric power at the mill of the company, Mr. Leggett naturally had exceptional facilities to investigate and study the merits of the electric system for mining installations, and these advantages, together with the several prominent features of construction and operation, he presents in the article in this number. He is a member of the American Institute of Mining Engineers, of the British Institute of Mining and Metallurgy, and of the Technical Society of the Pacific Coast.

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THE DITCH NEAR THE POWER HOUSE.

the distance from Bodie in a straight line over the hills to the east flank of the Sierra Nevada.

About two years ago, when the installation of this plant was under consideration, the limitations of the direct current for such a lengthy transmission were by no means as well established or as generally admitted as they are to-day. Therefore, when an eminent electrical engineer, and strong advocate of that system, coolly proposed to transmit the 120 horse-power required at the motor end of the line, by using the continuous current, with 5000 volts on the commutator of the generator, he was listened to with profound respect, not unmixed with the admiration that the eloquent electrician usually elicits from the untutored layman when he expatiates upon the possibilities of electricity, and asserts what can be done, though perhaps he may never have tried to do it.

Electricity has undoubtedly accomplished wonderful results during the past decade, proof of which was afforded in abundance at the Chicago World's Fair, but there are still some electrical feats that have not been previously attempted; and this, so far as the writer is aware, is one of them.

Near Genoa, Italy, a continuous current plant was recently installed transmitting 300 horse-power over a distance of eighteen miles to that place. At the power stations, of which there are three, one below the other, there are four groups of dynamos, each group of two dynamos driven by turbines on the Piccard system, of 140 horse-power, under heads varying from 225 to 495 meters. These are connected in series, one group being held in reserve, and produce each a current of 47 ampères and 1000 volts, the resulting electromotive force sometimes reaching 6000 volts during the hours of maximum load. The motors are also connected in series, no one machine carrying a potential exceeding 1000 volts at any time. This necessary series arrangement of dynamos and motors forms the great drawback to the use of the continuous current for long distance transmission, more especially where the range of work to be performed is wide and varied.

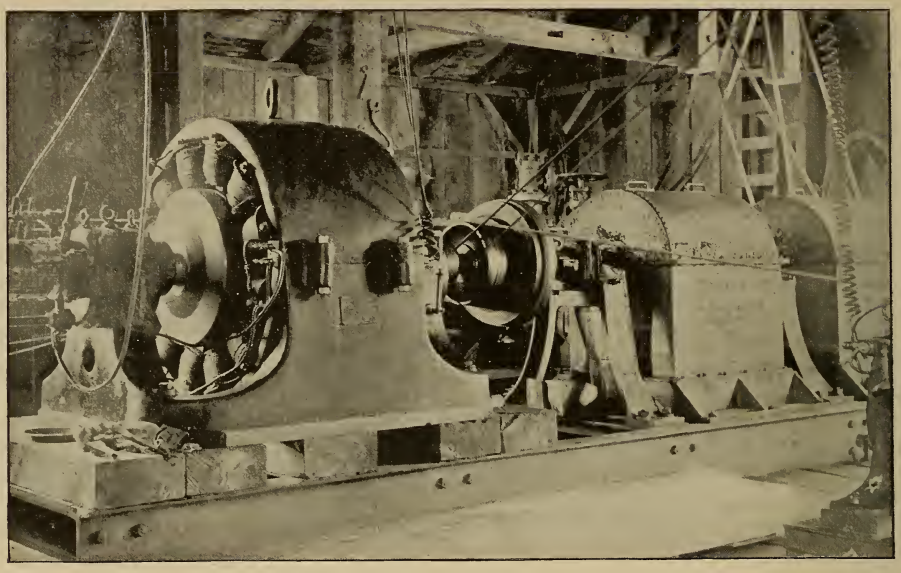
Nearly three years ago the Westinghouse Electric and Manufacturing Company in the United States installed a 120 kilo-watt generator for the San Miguel Consolidated Mining Company, at Telluride, Col., and transmitted 150 horse-power a distance of 3 miles by the single-phase alternating current synchronous system, suc-

cessfully operating the 40-stamp mill of the Gold King mine, the generator being driven by Pelton water-wheels and working under a potential of 3000 volts. Subsequently, this plant was increased by the addition of an 800 horse-power generator, from which current is transmitted 8 miles to a 250-horse-power motor, driving a 120-stamp mill of the same company. The excess of power is to be utilized in operating other stamp mills in the vicinity.

After consultation with Mr. W. F. C. Hasson, electrical engineer, of San Francisco, it was decided to adopt this single-phase synchronous system as the cheapest in copper and the simplest for the work required, and the contract for the electrical apparatus was let to the Westinghouse Electric and Manufacturing Company. At that time, neither the three-phase system, requiring three wires, nor the Tesla two-phase (requiring four wires) had reached their present state of development in the United States. In the Niagra Falls transmission, the above company is to use this two-phase system, which is undoubtedly better adapted to a variety of work than the single-phase, since the motors are self-starting.

An interesting installation of a three-phase plant has been made by the General Electric Company at Redlands, San Bernardino county, California, though the distance of transmission is but five miles. There are two alternating current generators of 250 kilowatt each, driven by four 30-inch Pelton water-wheels at a speed of 600 revolutions, double nozzles to each wheel. The differential governor described later on in this article is used. The generators carry a potential of 2450 volts. and the motor, about 2150, the line-loss being approximately 12 per cent. There are three No. 0, bare copper wires, insulated within the city limits, carried on deep-groove, double-petticoat glass insulators. This size of wire permits a subsequent enlargement of the plant. The line poles are 35 feet long, 6 feet in the ground and set 110 feet apart. The one motor at present in operation is a synchronous high-potential machine, of 150 horse-power, and has continuous work to perform in driving some ice machines. The initial current in the fields of the motor is generated by a small exciter, and the motor is self-starting only under light load, the full

ALONG THE LINE.



THE GENERATOR AND WATER-WHEELS.

load being thrown on after the machine is up to speed. The operation of this plant is stated by the manager, Mr. H. H. Sinclair, to be extremely satisfactory in every respect.

The General Electric Company has also a plant at Hartford, Conn., consisting of one 300 kilo-watt tri-phase generator, transmitting power 11 miles to one 300 horse-power synchronous, self-starting tri-phase motor. This motor, in turn, drives 500-volt direct-current railway machinery. The voltage of the tri-phase generator and synchronous motor is 500, and the line voltage 5000, obtained by means of step-up and step-down transformers. The company states that this plant has been in operation now for somewhat over ten months, and has given excellent satisfaction.

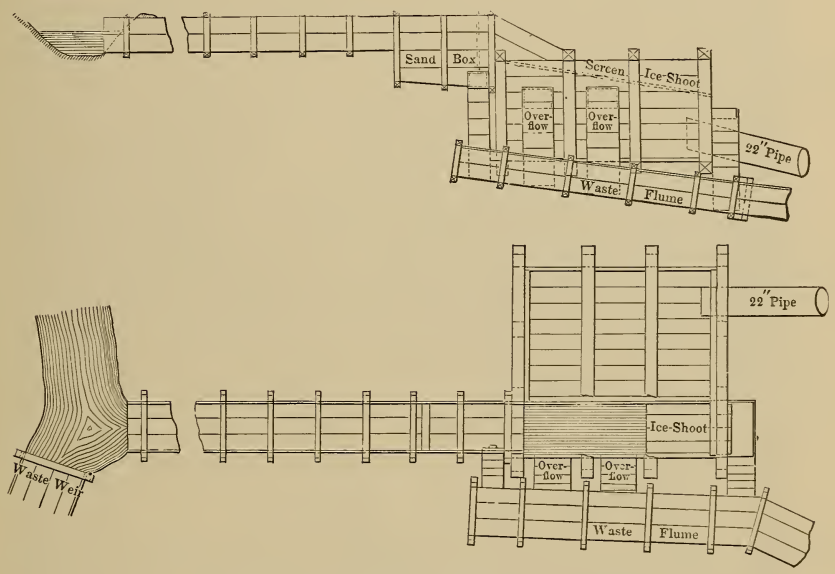
At Bodie, the distance of transmission, 12½ miles, is just at that intermediate point where the cost of transformers about equals the difference in cost between a No. 1 and a No. 6 copper wire (it is not advisable to use any lighter wire than No. 6, on account of its liability to rupture during storms). Hence, it was deemed better not to use converters, since they would only complicate the apparatus, without effecting a saving in cost.

An excellent water-power was found in a mountain stream on the north slope of Castle Peak in the Sierra Nevada, known as Green creek, and forming one of the chief sources of the East Walker river. This stream carries 400 inches of water during the dry season, and ten times that amount during the time of melting snows. An old ditch was cleared out and rebuilt for a length of 4570 feet and a site was selected for a power house, 355 feet vertically below its lower end. The ditch was made larger than necessary for power purposes alone, with the object of supplying other parties when there was an excess of water.

The diagrams on the opposite page show the connecting flume, pressure tank and waste-weirs. The arrangement of the screen adopted, while it occasions a loss of head of a couple of feet, is greatly to be recommended where "anchor" and slush ice form in a ditch during cold weather. The pipe is of large diameter, in order to permit subsequent enlargement of the plant, and also to reduce loss of head by friction. It is fitted with three

2½-inch air valves, to prevent collapse in case of sudden rupture, and is anchored at proper intervals with straps of 1¼-inch round iron. The slip joints extend to a vertical head of 220 feet, the remainder of the pipe being laid with collar and sleeve lead joints.

The pipe leads into a receiver, 40 inches in diameter and 9½ feet long, from which four taper pipes lead the water on, under a pressure of 152 pounds per square inch, to as many 21-inch Pelton water-wheels, each wheel being fitted with two nozzles, and rated at 60




ELEVATION AND PLAN OF PENSTOCK AND FLUME.

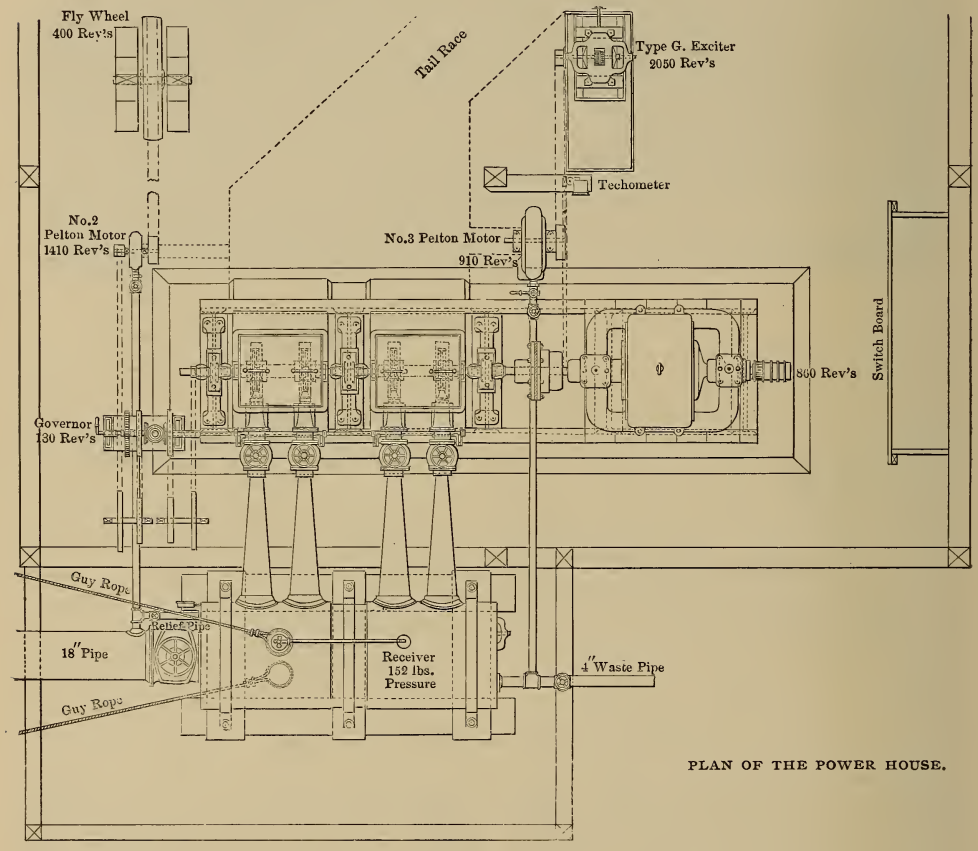
horse-power under the largest sized tips of 1⅓-inch diameter. The speed of the wheels is 860 to 870 revolutions, and their shaft is connected by an insulated, rigid coupling to the armature shaft of a 120 kilo-watt alternating current generator. The illustration on the page opposite shows the generator and water-wheels in operation.

The plan on the next page shows the arrangement of the plant, one of the most interesting features of which is the water-governor formerly known as the "Doolittle," and now called the Pelton differential governor, represented on page 364. It operates butterfly valves placed in the 5-inch pipes between the gate valves and the diverging nozzles; and though this form of valve invariably "throttles" the water to a greater or less extent, according to the position of the valve, it is a most satisfactory way of controlling the power where the latter is ample, and the loss due to this cause is of slight consequence. The governor operates as follows:

Two 18-inch pulleys revolve loosely and in opposite directions on a shaft, one being driven from the water-wheel shaft and the other by a No. 2 Pelton motor. These pulleys have gears on their hubs which mesh into two other gear wheels, carried on an axis at right angles to the shaft and keyed fast to the latter. Beyond these wheels is a pinion, loose on the shaft and with ratchet teeth cut in opposite directions on either side of its hub. Into these ratchet teeth mesh corresponding circular ratchets, which are keyed to the shaft but free to move longitudinally along it, and are thrown in or out of gear by a short lever and spring. The pinion engages a sector, which is

fastened to the rod and levers that operate the butterfly valves, and on the same rod is a hand lever, by means of which the valves may also be opened or closed by simply throwing out of mesh the circular ratchets alluded to and thereby detaching the governor. It is evident that when the two pulleys are revolving in opposite directions at exactly the same rate of speed, there will

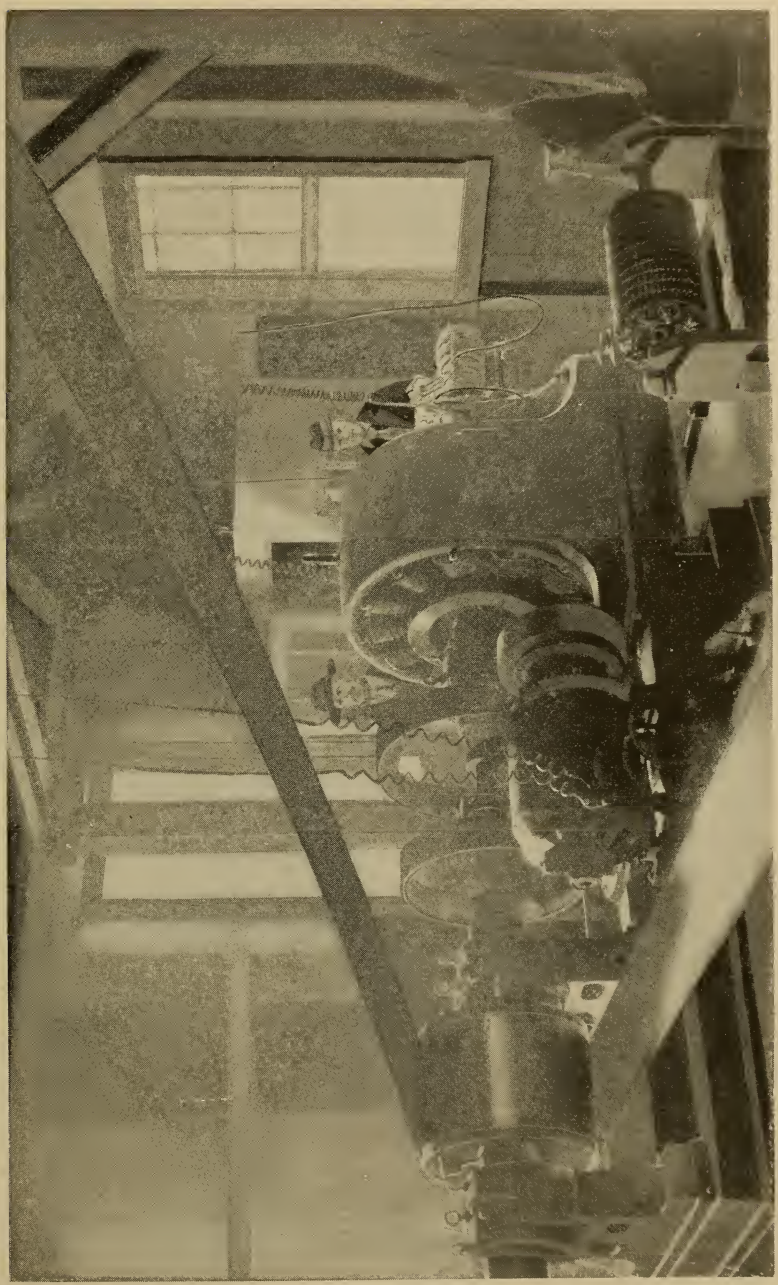
In starting up from rest, the governor is detached by throwing out the springs on the ratchets, and the valves are operated by the hand lever. After the wheels are at normal speed and the load is on, the ratchets are sprung into gear with the pinion, and the governor takes care of any and all variations, even to a complete throwing off of the load, by pulling the main current plug switch at



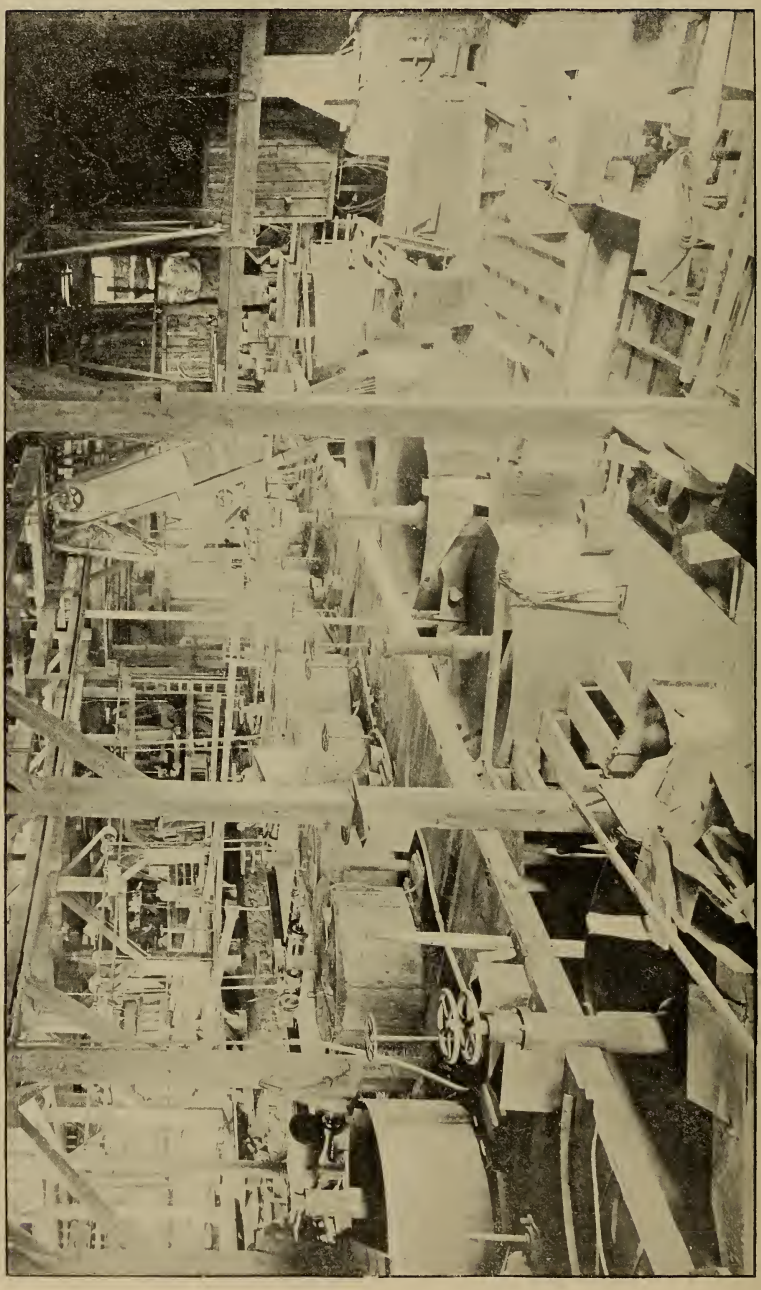

PLAN OF THE POWER HOUSE.

be no motion of the central gear shaft, and none will be communicated to the pinion and sector and thence to the valves, to open or close them; on the other hand, a difference in speed of these pulleys will have the opposite effect. The belts driving them are therefore so arranged that a decrease in speed of the water-wheels will open the valves, and an increase will close them.

Bodie. The speed of the governor pulleys, as first designed, was 60 revolutions. This was found to be too slow, and it was increased to 180 revolutions with most beneficial effects, developing a greater sensitiveness to small changes of load, and much quicker action, especially when all the load was thrown off at once. In the latter case, the increase in speed of the water-wheels did not at any time exceed 12



THE MOTOR IN OPERATION.



INTERIOR OF THE 20-STAMP GOLD QUARTZ MILL OF THE STANDARD CONSOLIDATED MINING COMPANY AT BODIE, CAL.

per cent. before the governor began to close the valves.

It was further found necessary to furnish a constant resistance for the water motor, that drives one side of the governor, to work against. In the original plan this was to be done by the exciter which furnishes current for the fields of the generator; but, on trial, it appeared that the load on the exciter was too variable, and at times too great for the little motor to take care of. The exciter was then placed so that it could be driven by either a larger size (No. 3) motor or by the water-wheel shaft coupling (see plan of power-house), and a fly-wheel of about 1500 pounds weight was set to be driven by the smaller motor and insure its constant speed.

The great drawback to the use of water-power for the generation of electricity has hitherto been the lack of a good water governor, sufficiently sensitive and quick-acting to insure the vital factor of constant speed without bringing dangerous strain on the water pipe. In fact, in the Westinghouse plant at Telluride, and in several others of which the writer is aware, the "one-man automatic regulator" had to be used; *i. e.*, a man sat with his hand on the lever of a deflecting nozzle and his eye fixed on a voltmeter or a tachometer. The above described governor is so great an improvement over this system that its operation has been given in detail.

The generator is a Westinghouse 120 kilo-watt, constant potential, 12-pole machine, and its armature shaft is attached to that of the water-wheels by a rigid coupling, insulated by a disc of harb rubber, one inch thick, and projecting one inch beyond the flanges, while the bolts are surrounded by bushings and washers of insulating fibre. The initial current in the lower half of each field coil, or the winding nearest the armature, is instilled by means of a direct-current exciter. The secondary winding on the armature spokes of the dynamo generates current when the machine is under load, which is led to a 12-bar commutator on the armature shaft and thence to the compensating winding which occupies the upper half of each field bobbin.

As the load on the generator increases, more current flows through its armature coils and through a primary winding on the armature spokes, thereby inducing, in the secondary winding, a heavier current, which, being led to the magnetic field as described, proportionately strengthens the same. When the generator is running without load, there being little or no current in its armature coils, none is induced in the secondary winding, and the compensating winding on the fields is without magnetic effect until the latter is required by work to be performed. The potential of the generator under full load is 3530 volts, but at present it is operating with about 3390. The exciter carries a voltage of from 105 to 112.

The length of the wire line is 67,760 feet, or 12.46 miles. The poles are of round tamarack timber, 21 feet long, 6 inches in diameter at the top, set 4 feet in the ground, poles 25 feet long being used through the town and along the line wherever there is danger of deep snow-drifts. They are placed 100 feet apart, and fitted each with a 4 x 6 inch cross-arm, boxed into the pole, and held by one bolt and one lag screw. The line crosses extremely rough country, not 500 yards of which is level beyond the town limits. Most of the ground is very rocky, over 500 pounds of dynamite being used in blasting the pole holes.

The wire is of No. 1, B. & S. gauge, soft-drawn bare copper, and is attached to standard double-petticoat deep-groove glass insulators. The wire was first attached to the insulators by tie-wires of No. 10 galvanized iron wire. Later, it was found advisable to insulate the line-wire at the insulators, and for this purpose ordinary sheet rubber, $\frac{1}{8}$-inch thick, such as is used for gaskets, was cut into strips 1.5 inches wide and 12 inches long. These were wound spirally about the wire and held in place by two close wrappings of Manson's tape. The whole was then well daubed with asphalt paint, and the insulated wire re-attached to the insulators by

tie-wires of No. 6, weather-proof copper wire.

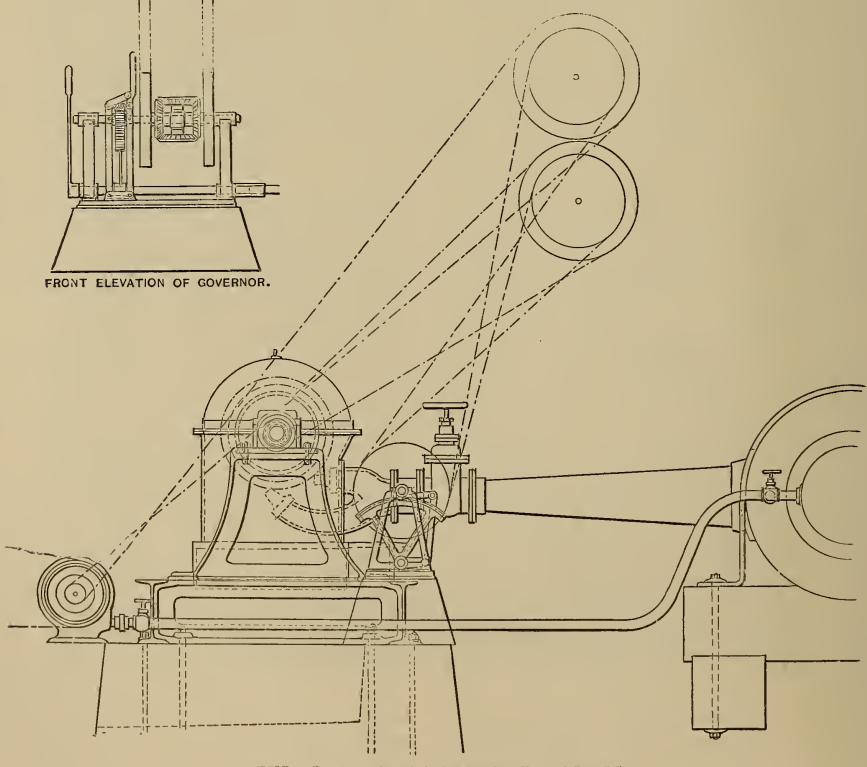
The line crosses a number of very steep ridges, from 300 to 800 feet in height, and on these the wire necessarily pulls heavily on the top pole, and especially on its pins and insulators. In all such places the ordinary double-petticoat insulators were replaced by large special insulators, on which the wire is carried in a groove across the top, and its weight is therefore directly down upon, and in line with the centre of, the pin. The line has given no trouble whatsoever, and has carried the high potential of 3000 volts without a leak, even during a severe storm of ten hours' duration, the rain changing to sleet and ice toward the end; but this severe test, it must be admitted, occurred after the wire had been wrapped at the insulators as described. In fact, one of the chief objects of this insulation was to render the line proof against just such a storm as this. Snow-storms have no effect whatever.

The motor that drives the stamp mill of the Standard Consolidated Mining Company at Bodie is an alternating current synchronous constant potential machine of 120 horse-power. The mill contains twenty 750-pound stamps, 4 wide-belt (6 feet) Frue vanners, 8 continuous process amalgamating pans (two of which are constantly grinding), 3 settlers, 1 agitator, 1 pan and settler devoted to the amalgamation of concentrates, a bucket elevator, a worm-gear hoist and a rock crusher.

On the armature shaft of the motor is a friction wheel, and beyond this is a clutch, which is used to set in motion the driving pulley and the machinery of the mill. On the same bed-plate with the motor is a small 10 horse-power Tesla starting motor, with a wooden pulley on its shaft, that is brought to bear against the friction wheel mentioned by means of a screw



FRONT ELEVATION OF GOVERNOR.



END ELEVATION OF THE WATER WHEELS.

and hand wheel. This Tesla motor consists simply of field coils and an armature ; it has neither brushes nor commutator, nor sliding contacts of any kind. The alternating current is led directly into the fields, the coils of which, being connected in series, produce a rotating magnetic field, in that each pole is alternately positive and negative.

The starting torque of the armature is in consequence very low, and it has to receive several rapid turns by hand before putting on the current, after which it generally runs up to normal speed (1660 revolutions) within a minute. By means of a single countershaft, fitted with self-oiling boxes, the high speed of the motor (860 revolutions) is reduced to the necessary 80 revolutions of the battery line shaft, the reduction being 2 feet to 8 feet and 3 feet to 8 feet. Light, steel-rim, balanced pulleys are used, and an endless 16-inch, double, leather belt runs from the motor to the first 8-foot pulley. The speed of this belt is 5400 feet per minute, and it is kept tight by levers which, acting through screws, move the entire motor and its bed plate along four grooved cast-iron slides.

The motor is separated from the underlying brick foundation by means of 8 x 10-inch timbers, which are bolted to the latter and covered by three layers of 1-inch boards ; and to this wood insulation the slides referred to are fastened by lag-screws that pass through the boards into the timbers. The generator is insulated from the I beams that carry both it and the water-wheels by timbers 5½ inches thick, to which it is likewise secured by lag-screws.

The mill and offices of the company are lighted by 100-volt incandescent lamps, taking current from a large 100-light converter, ratio 30 to 1, which is attached to the main line in the motor room, before it reaches the switchboard. The light is very satisfactory, even to read or write by, although at times the lamps flicker slightly, due to small changes of load. This variation of intensity is, of course, unavoidable where the lighting current is taken direct from a power circuit ; but, in the present case at least, is not sufficiently noticeable to cause inconvenience.

The efficiencies of the machines, namely, of the generator 95.5 per cent. and of the motor 93.9 per cent., were determined by Mr. Fred H. Davis, electrical engineer of the Westinghouse Electric and Manufacturing Company, in charge of the plant. In reference to these tests Mr. Davis says :

"As there were no instruments available by which the mechanical losses could be determined, or by which the relative position of the current and electro-motive force phases of the load could be ascertained, these two conditions could only be judged of in a somewhat remote way. As the generator is directly and rigidly coupled to the water-wheels, and has but two bearings, both of which are amply large, and run without heating under full load, it is fair to assume that the mechanical loss of power in this machine is very small. The motor is running under equally favourable conditions, being connected directly to its work by a clutch.

"The condition of the phase of the line current was judged of in the following manner :—The apparent horse-power delivered to the motor, obtained from readings of the line current and electro-motive force at the motor station, almost exactly agrees with the mechanical horse-power required to drive the same load from an engine, the amount of work done being determined from indicator cards taken from the cylinder of the engine. This close agreement between the work done by the engine and that apparently done by the motor on the same load, indicates that there is but very little shift or lag in the phase of the current delivered to the motor, and therefore the apparent efficiency of these machines is, for all practical purposes, the true electrical efficiency."

The proper setting of the brushes on the commutator of the motor armature is a knack acquired only by experience, and, for a while, considerable trouble was caused by undue sparking at these

brushes. Experience on the part of the attendants has entirely overcome this ; but it has been found necessary to use two commutators, keeping one always turned and polished ready for use, and changing them usually after 25 or 30 days of steady operation.

The dependence of the motor speed upon the alternations of the generator is very prettily shown, when, without pulling the line plugs, the machines are stopped by shutting off the water on the wheels. The motor then slows down in exact accordance with the generator, and is at rest within half a minute or so ; whereas, when the plug is pulled in the usual way, the motor armature will revolve for several minutes from its own momentum, before coming to a stop.

The first trials of this plant developed electrical defects resulting in accidents more or less serious to both machines ; and Messrs. Reed and Winslow, Westinghouse engineers, deserve much credit for the manner in which they met and conquered these difficulties. There was no trouble with the wire-line—it has carried the 3000 volt current through all kinds of weather—but the current succeeded in escaping at the machines themselves, through brush holders, and armature coils, and even at the synchronizing jaw-switch. In almost every instance, the remedy was heavier insulation at the point of escape, resulting almost invariably in a cure of the evil.

The plant has accomplished several unbroken runs, day and night, one of thirteen days' and another of twenty days' duration, but latterly it has been operated more intermittently, on account of the mill being run upon only half-time. During December, 1893, the plant was started twenty-three times in twenty-one days, and in January, eleven times in as many days (in accordance with the requirements of the milling work), these daily startings being an excellent test on both the starting motor and machines, as at such times the differences in potential, and consequently the strain on the insulation, are likely to be a maximum. At present, the plant is operating most smoothly, and is successfully demonstrating the effectiveness and simplicity of the single-phase synchronous system for such work and distances, while the daily saving over the use of steam, on twelve-hour runs, is from $35 to $40. The writer takes pleasure in acknowledging the aid of his assistant, Mr. R. C. Turner, E.M., in the preparation of the accompanying drawings.

The protection of the circuits against lightning is a very important matter. The mountainous regions in which the majority of mines are located are generally subject to severe thunder storms and electrical disturbances, and, therefore, to the miner using electrical power it is of vital importance to have his apparatus protected from damage from such causes. Many may, in fact, be deterred from undertaking the installation of electric transmissions through fear of lightning interfering too seriously with their continuous operation.

To secure this protection, lightning arrester houses have been built at each end of the line, close to the power-house and motor room, and these have been fitted up with four banks of spark gap arresters and impedance or "choke" coils, each coil being made up of 17 turns of No. 1 wire. This arrangement was made in accordance with the plans of the inventor, Mr. Jay Alex. Wurz, lightning expert of the Westinghouse Company.

The coils act as electrical dams, shunting the lightning over the gap arresters and to the earth, which path it takes in preference to forcing its way against the high induction of the former. In addition to the 8 coils on each leg of the line in the two "arrester" houses, there are two more in each station, making twelve on each line, or twenty-four in all. Inductive resistance grounds have also been added at either end of the line, with the object of preventing damage to the machines from static charges, by leaking them to earth as fast as accumulated.

The matter of proper earth connections at the terminals of the ground wires is most important. The common

THE MOTOR-SWITCHBOARD.

idea that a rod of iron, stuck into the earth a couple of feet, or thrown into the bed of a running stream, forms a good "ground" is most erroneous; in reality this forms the poorest kind of earth connection. The ground wires from the banks of arresters are carried into a pit dug directly underneath the arrester-house. This pit is about four feet square, and reaches to permanently moist earth in one case, and in the other, since such could not be found, it was necessary to carry a small pipe into the pit, through which to occasionally supply water. On the bottom of the pit a layer of small charcoal, two feet in depth, was laid, and on this was placed a plate of old copper, about one-sixteenth of an inch thick, and two feet by three feet in area. To the plate the ground wire was securely soldered in a spiral coil, and another layer of charcoal placed on top of it, after which the pit was filled up with loose dirt. This makes an efficient "ground," and gives the necessary surface for the rapid dissemination of the electric discharge. Since the installation of the above described apparatus in August last, the plant has continued in operation through one severe thunder storm and several high windstorms, accompanied by clouds and atmospheric disturbance, without any damage whatsoever to the machines, and there is no doubt but they are thoroughly protected against all ordinary discharges of lightning.

Since the destruction by fire, several months ago, of the extensive hoisting works of the company, it became necessary to either rebuild a steam plant, or extend the electrical system to the underground work, and the latter plan is the one that has been adopted. It is well known that for hoisting or similar work, where full-load is thrown at once upon the motor, a single-phase synchronous motor will not answer, nor indeed have any but direct-current machines yet been used for such purposes. The method has, therefore, been adopted, of driving a 100 horse-power, 550-volt, direct-current generator by belt from the present motor, and using this current in a 45 horse-power underground hoist. The remaining power will be utilized in operating a 25 or 30 horse-power pump motor, a 10 horse-power surface hoist, to be used in hauling cars up an incline, and a small 2 horse-power motor for a centrifugal pump in the tailings plant. We have here an excellent instance of the ease with which electric power can be applied to all extensions of surface works.

This tailings mill—if a leaching process can be so termed—has a capacity of 100 tons per day. The handling of loaded cars by electric power will do away with the present more expensive method of hauling by wagon and teams, while the substitution of a motor for the small engine and boiler now used to run the pump needed for elevating the leaching solution is an important economy, besides lessening the ever-present fire risk.

The writer has several times been asked whether electric power transmission was a success after all. To such doubting inquirers it can only be pointed out that the plant described is operating day and night, week after week, without stops long enough to lower the temperature of the machines, oftentimes without any at all until the seventh day, when a few hours suffice to go over the machines, switchboards and connections, and see that all is in order. The power is smooth, steady and reliable; while its cleanliness, compactness, ready divisibility into smaller units, ease of transmission from point to point about the plant, and ready applicability to all classes of work where both alternating and direct-current are used make it the ideal power, and one with a grand future in the field of mining work alone.

A LOCOMOTIVE CRANE IN QUARRY SERVICE.

# LOCOMOTIVE CRANES.

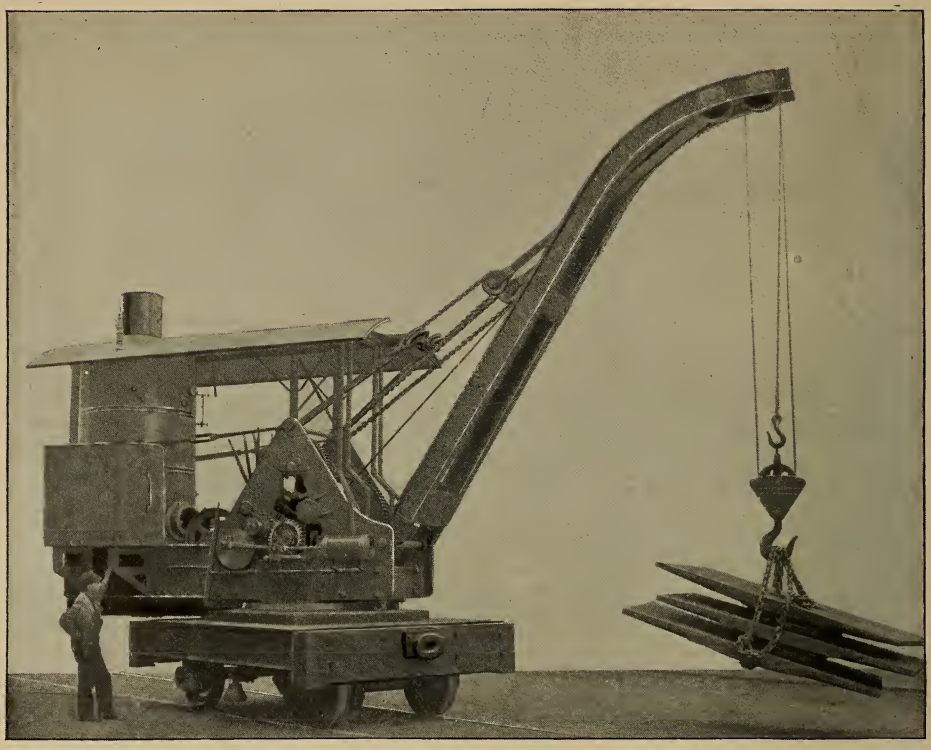
*By Wm. L. Clements, M. Am. Soc. M. E.*

A CRANE which is mounted upon a car and has the motions of self-propulsion, hoisting and slewing is known as a locomotive crane. In general the design consists of a car supported by four or eight wheels, having mounted upon it machinery frames, engine and boiler, and the necessary gearing, clutches, brakes and other appliances, for the proper operations of hoisting the load, slewing it to any position within the radius of the jib, and carrying it suspended from the jib, through the function of self-propulsion.

This type of crane has such general and increasing use that a classification and consideration of designs for specific uses are important and necessary in the determination of designs for proposed uses. In general these cranes may be divided into locomotive cranes for mercantile uses and locomotive cranes for railway uses.

As to locomotive cranes for mercantile uses, the use of a locomotive crane about a manufacturing plant, rolling mill or blast furnace, has established a type for this service. Its use in hand-

WILLIAM L. CLEMENTS has long made a specialty of crane machinery and other special appliances for railroads. As chief engineer of one of the largest crane and steam shovel companies in the United States his work has become well known and his designs of locomotive and railroad cranes are among the largest and most powerful built in America.



A FIFTEEN-TON CRANE.

ling materials of construction in quarry work for loading stone, has developed another type. The machines belonging to cranes for mercantile uses are different in many details from those suitable for railway uses and for service in construction or wrecking.

On the next page is presented a crane of large capacity, designed for use about steel-works and manufacturing plants. The machine has a capacity of fifteen tons at a radius of sixteen feet, and of twelve tons at a radius of twenty feet. It is of the heaviest design yet constructed for operation upon standard gauge tracks. On the page opposite is shown a design of ten tons capacity for the same general use, lifting this load at 12-foot radius, or a load of six tons at a 20-foot radius. The design shown on page 374 is intended for lighter service and for loads of five tons at a 12-foot radius, or three tons at a 20-foot radius.

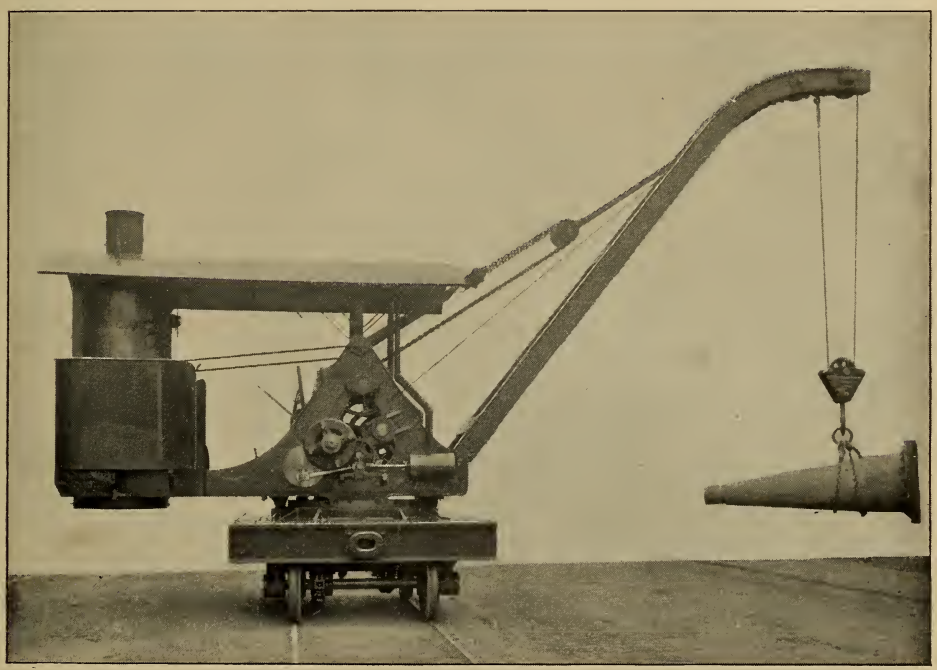
In general design, cranes for this service are mounted upon four wheels with axles and journals running in rigid boxes without springs. The axle centres vary in distance apart, depending upon the gauge of the supporting track and its curvature. The car frame is generally weighted in cranes of large capacity, ensuring stability to the machine. These cranes are provided, when desired, with outriggers, or telescopic beams, jacks and clamps for taking extreme lifts with the jib at right angles to the car. Such appliances are for extraordinary use, and when the machine is to work ordinarily at its full capacity, and at right angles, the car and frame-work are made to lift this load in all positions without the use of these outriggers. The service of car-shifting is frequently required, and the crane must have sufficient power to propel itself, and with from two to six loaded cars.

The ordinary use of locomotive cranes

in these services render unnecessary an extended description of their work. Suffice it to say, that in the manufacture of many articles of weight and bulk, requiring storage, transportation or manipulation, the locomotive crane is a most valuable adjunct.

The use of a locomotive crane in quarry work is generally for piling, storing and shipping stone. In this work it is frequently necessary, where storage space is limited, to pile as high and high lifts a large factor of stability is necessary ; hence, a very heavy car body and counterweight. For high lifts rapid speeds of hoisting and precision in slewing are required. Here, too, it is desirable for the crane to do car shifting, and this feature is frequently of great importance.

On the opening page of this article is shown a locomotive crane like the one described, at work in a quarry, loading stone for shipment up-



A TEN-TON LOCOMOTIVE CRANE.

as safety will permit, so that the material may be easily accessible for future handling or shipment. For such uses, it is important to have a long jib for height in piling, and as the machine operates at nearly all times with the jib at right angles to the car, the maximum capacity must be lifted without the aid of outriggers. For economy of space and effective radius realized, as the crane swings a complete circle and often between piled stone on either side of the track, a short rear extension of the boiler is desirable. For the heavy loads on cars from the piles at the sides of the track. Its use for such work obviates the necessity of many fixed cranes, and its area of operation is limited only by the length of the track carrying it.

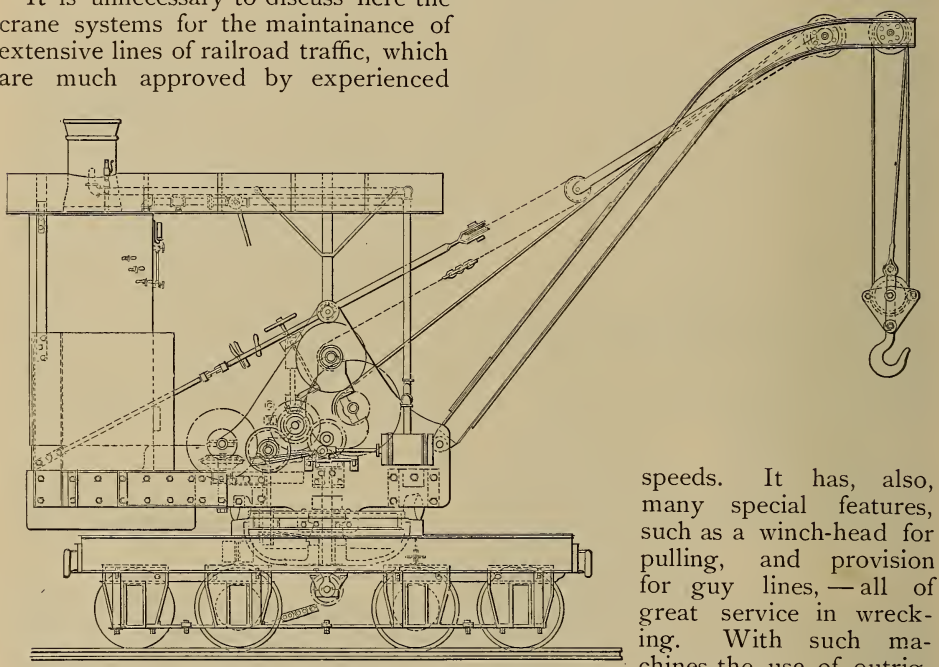
The designs of locomotive cranes thus far mentioned are illustrative of the types for mercantile uses ; other designs might be shown differing only in minor details for specific uses. The construction and operating departments of a railroad, however, have many uses for a crane which has the convenience of one of the locomotive type. In the

department of construction, the erection of bridges, abutments, turntables and much other work, necessitates crane machinery, and the portable machine fulfills economical service better than all others. In the operating department, to the management of which is entrusted the care of rolling equipment and the clearing away of obstructions to traffic in case of breakdowns or wrecks, the use of a proper crane is of prime importance.

It is unnecessary to discuss here the crane systems for the maintainance of extensive lines of railroad traffic, which are much approved by experienced men. It is true, however, that all extensive lines have portable cranes for use in this service, and with the increasing weight of equipment the advantages of power cranes have been made manifest. Special cranes are constructed for this service and have a capacity greater than it has yet been possible to provide for a locomotive crane ; but with these special machines, with capacities as high as thirty-five tons, there are disadvantages in operation which may not compensate for such increased capacity.

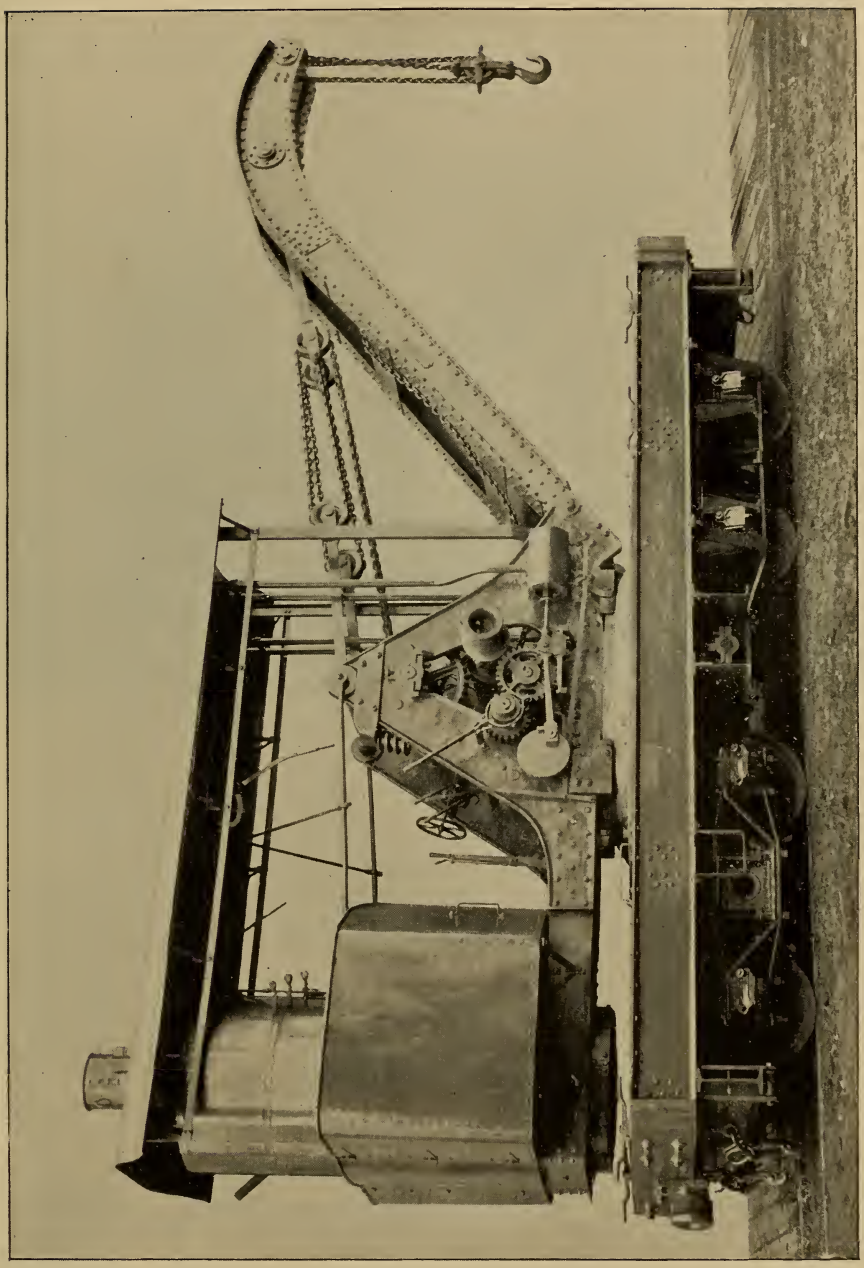
Upon standard-gauge tracks it has not been found expedient to construct a locomotive crane in capacities exceeding twenty-five tons, there being objection to excessive weight and the narrow wheel base, moreover, being a deterring factor.

On the page opposite is shown a crane constructed in capacities from fifteen to twenty-five tons. Its peculiar design with reference to those before shown is in the longer car and its mounting upon trucks, so that the machine may be embodied in trains and run at high speeds. It has, also, many special features, such as a winch-head for pulling, and provision for guy lines, — all of great service in wrecking. With such machines the use of outriggers, when making maximum lifts, is permissible and necessary. In further explanation of this machine it may be said that whilst its capacity is insufficient to lift the heaviest locomotives, yet by its peculiar design an expert operator, by the pulling process, may roll-over, or pull heavy engines up an enbankment on to the track.

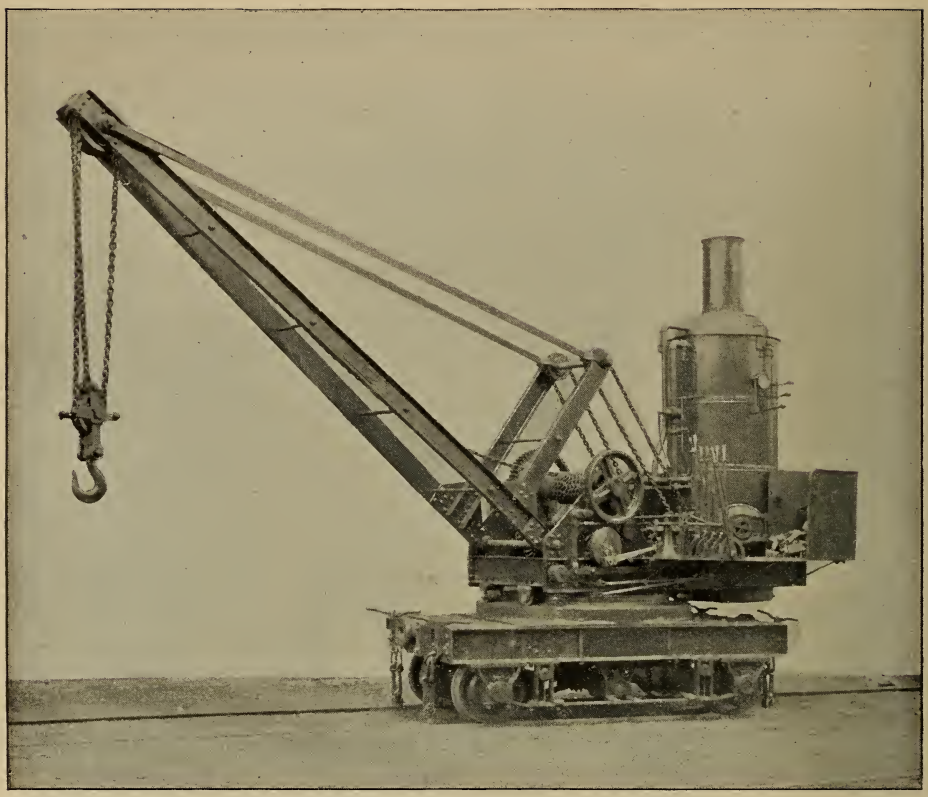


GENERAL DESIGN OF THE HEAVIER TYPES OF LOCOMOTIVE CRANES.

The diagram on this page illustrates, in outline, the general design of the heavier types of locomotive cranes previously shown. Among the merits of this design are the economy and advantageous use of material, the ease with which the various motions are manipulated, and the completeness of the mechanical details.



A RAILWAY LOCOMOTIVE CRANE.



A FIVE-TON CRANE FOR LIGHT SERVICE.

The base plate, or main foundation casting, to which many of the stresses, due to the load, are communicated, is saucer-shaped, having, at the bottom of the concavity, a steel centre-pin, and upon the outer surface the roller path is accurately turned. In the process of lifting, the pin is in tension and the marerial of the base casting in compression,—the most advantageous conditions. The gearing is of cast steel, and the clutches for the more important motions are of the friction type. It is considered desirable in many designs of these machines that they shall travel over tracks of the smallest possible curvature, rendering their service available in positions otherwise inaccessible. The running gearing is, thus, an important detail. It is found that with chain of suitable material and strength a greater end play for the journal bearings supporting the crane is permitted, and the machine not only may traverse curves of small radii, but the flange and journal friction is much less than with rigid connections required with gearing, and the crane is capable of driving itself more rapidly and is able to pull heavier loads.

The machines are made mechanically complete by the additions of a jacket of asbestos wood and planished iron for the boiler and cylinders, and a canopy, protecting the attendant from the weather.

# A REMARKABLE STEAM ENGINE PERFORMANCE.

*By Charles T. Porter.*

IN *Engineering* of August 17, 1894, there was published a report of two trials, conducted on June 21 and 26, 1894, with a triple expansion engine, built by Messrs. Victor Coates & Co., Limited, of Belfast, for the Brookfield Linen Company, Limited, of the same town, and which had then been in use for about nine months. The report is accompanied by a full set of diagrams, which are stated to be the average of the diagrams taken on the two trials, respectively. The diagrams, together with the tabular report of the trials, are reproduced on the following pages.

The reported results of these trials are of an extraordinary character. They appear to show that the weight of dry steam used in the engines, after making the small deduction of one per cent. for the priming of the boilers, was, on the first trial, only 11.75 lbs., and on the second trial, only 11.52 lbs. per indicated horse-power per hour.

The engines were of the simplest form. The cylinders were not steam jacketed, and no intermediate reheaters were used. The first and second cylinders exhausted into chambers between the cylinders, which chambers appear to have served as steam chests for the second and third cylinders, respectively. This arrangement of course caused considerable wire-drawing of the steam in the second and third cylinders, which is shown on the diagrams. The steam was not superheated.

The diameters of the cylinders were 19″, 29″ and 46″, the stroke was 48″, and the number of revolutions per minute was 76. The areas of the cylinders were, thus, 283.53, 660.52 and 1661.91 square inches, the proportions being 1, 2.35 and 5.862, and the piston travel was 608 feet per minute. The pressure of steam carried was 160 lbs., by gauge. The duty which appears to be shown on these trials is so low, that I have been led to give them a critical examination. The results of such examination are presented in this paper.

According to the diagrams, which I have measured, the amount of power exerted is given correctly, as follows: On the first trial,—high pressure cylinder 264.1, intermediate cylinder 266.7, and low pressure cylinder 264.7, making a total of 795.5 indicated horse-powers; on the second trial, high pressure cylinder 225.66, intermediate cylinder 297.24, and low pressure cylinder 251.68, making a total of 774.58 indicated horse-powers. The weight of water given as evaporated per hour was, on the first trial, 9343 lbs., and on the second trial 9106 lbs. It would seem that these must have been the full weights of water evaporated, for they show the actual evaporation from the combustion of one pound of coal to have been 11.55 lbs. and 11.63 lbs., and from and

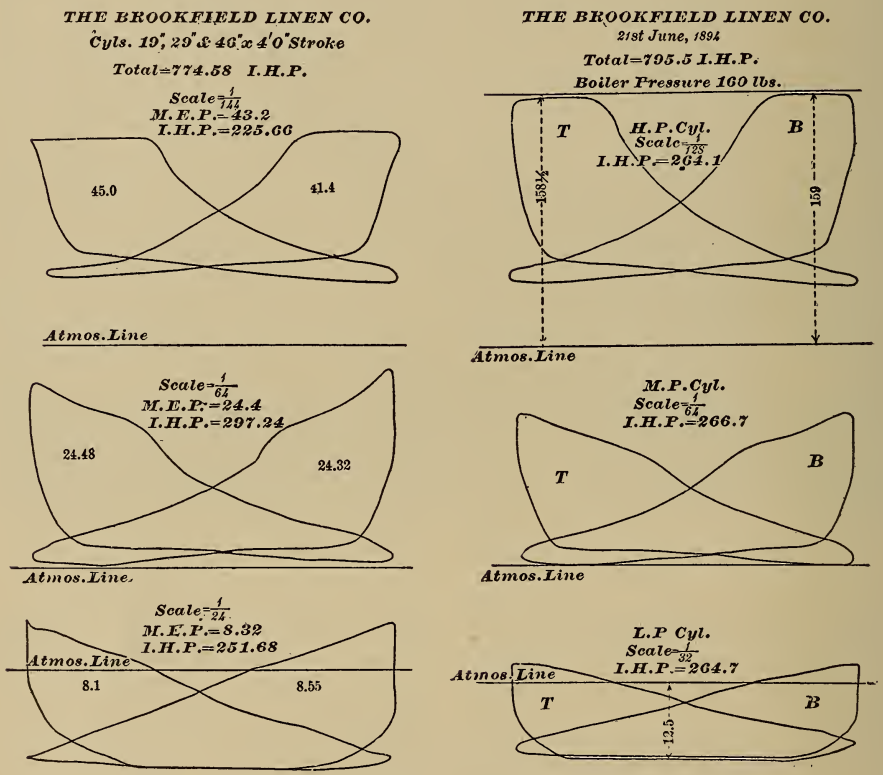
CHARLES T. PORTER, though originally having followed the practice of law, early in his career took up the study of mechanical engineering and acquired an international reputation in his later profession. He made an exhaustive study of the theoretical and practical conditions involved in the employment of high rotative speeds in stationary steam engines, and was the first one to build engines in which such speeds were successfully attained. About the year 1860, Mr. Porter became associated with John F. Allen in the Porter-Allen engine. The valves and valve motion of this engine were the invention of Mr. Allen, and were the earliest means by which an automatically varied expansion was obtained with valves having positive movements. All the constructive features which were for some time peculiar to this engine, but most of which are now in general use, were designed by Mr. Porter, and the Porter-Allen engine became well known on both sides of the Atlantic as the pioneer high-speed engine and proved itself an almost instantaneous success.

at 212°, 13.9 lbs. and 14 lbs., on the two trials respectively. It will conduce to greater clearness if the results of the two trials are considered separately.

FIRST TRIAL.—In discussing this trial, I desire for the present to confine attention to the diagrams from the high pressure cylinder. In this cylinder the pressures obtained, which were 158½ lbs. on one stroke and 159 lbs. on the other stroke, gauge pressures, were maintained very nearly to the point of cut off, and the expansion was carried practically to the end of the stroke. The terminal pressure was 50 lbs. plus the atmosphere in the right hand diagram, and 44 lbs. plus the atmosphere in the left hand diagram. The piston displacement in this cylinder was 72,000 cubic feet per hour.

The amount of waste room is not given, and the diagrams afford no satisfactory indication of it. I assume it, in this cylinder, to add 5 per cent. to the piston displacement, which cannot be far wrong. This adds 3600 cubic feet, making a total of 75,600 cubic feet of steam per hour. The total terminal pressure, mean of the two strokes, was 61.7 lbs. on the square inch. At this pressure the weight of one cubic foot of steam is 0.15 of a pound, and the weight of 75,600 cubic feet is 11,340 lbs.

From this amount there is to be deducted the weight of the steam saved by the compression. The point of compression cannot be fixed on the diagrams with precision. My method is to select a point when the compression has certainly taken place, and to measure the volume and pressure of the steam at that point. The point selected is at 0.135″ from the end of the diagram. The total length of the dia-




DIAGRAMS FROM A 1000 HORSE-POWER TRIPLE-EXPANSION MILL ENGINE.

TEST OF 1000 HORSE-POWER TRIPLE-EXPANSION MILL ENGINE.

Cylinders 19 in., 29 in. and 46 in. in diameter by 4 ft. stroke. Suitable for 1000 indicated horse-power.

| | First Trial. | Second Trial. |
|---|---|---|
| Date of trial | June 21 | June 26 |
| Duration of trial | 3 hours | 3 hours |
| Steam jackets | None | None |
| Sequence of cranks | H. M. L. | H. M. L. |
| Boilers | 2 Lancashire | 2 Lancashire |
| Dimensions of boilers | 7 ft. 6 in. × 30 ft. | 7 ft. 6 in. × 30 ft. |
| Diameter of flues | 3 ft. | 3 ft. |
| Conical tubes in each boiler | 10 | 10 |
| Economizer, "Green's;" number of pipes | 360 | 360 |
| Heating surface in two boilers | 1,900 sq. ft. | 1,900 sq. ft. |
| Heating surface in economizer | 3,600 sq. ft. | 3,600 sq. ft. |
| Total heating surface | 5,500 sq. ft. | 5,500 sq. ft. |
| Total grate area | 70 sq. ft. | 70 sq. ft. |
| Ratio of $\frac{\text{grate surface}}{\text{heating surface}}$ exclusive of economizer | 1:27 | 1:27 |
| Ratio of $\frac{\text{grate surface}}{\text{heating surface}}$ inclusive of economizer. | 1:78 | 1:78 |
| Class of coal used | Vivian's through and through | |
| Total weight of coal used | 2,428 lb. | 2,352 lb. |
| Total weight of coal used per hour | 809 lb. | 784 lb. |
| Coal burnt per square foot of grate surface per hour | 11.5 lb. | 11.2 lb. |
| Coal burnt per square foot of total heating surface per hour | .147 lb. | .142 lb. |
| Total quantity of water evaporated | 28,030 lb. | 27,320 lb. |
| Total quantity of water evaporated per hour | 9,343 lb. | 9,106 lb. |
| Water evaporated per square foot of grate surface per hour | 133.6 lb. | 130.1 lb. |
| Water evaporated per square foot of heating surface per hour | 1.70 lb. | 1.65 lb. |
| Water evaporated per pound of coal | 11.55 lb. | 11.63 lb. |
| Water evaporated per pound of coal from and at 212 deg. | 13.9 lb. | 14.00 lb. |
| Mean steam pressure in boilers | 160 lb. | 166 lb. |
| Mean vacuum in condenser (gauge) | 27.75 lb. | 28.25 lb. |
| Mean vacuum in low pressure cylinder (indicator) | 12.25 lb. | 12.50 lb, |
| Mean temperature of injection water | 65 deg. | 65 deg. |
| Mean temperature of overflow water | 85 deg. | 90 deg. |
| Mean temperature of feed water | 60 deg. | 59 deg. |
| Mean temperature after passing through economizer | 259 deg. | 247 deg. |
| Mean temperature of steam in boiler | 371 deg. | 373 deg. |
| Mean indicated horse-power | 787.4 | 782.7 |
| Mean revolutions per minute | 76 | 76 |
| Mean pressure referred to low pressure cylinder | 25.8 | 25.56 |
| Net water per indicated horse-power per hour | 11.86 lb. | 11.63 lb. |
| Amount of priming, not measured, allow | 1 per cent. | 1 per cent. |
| Net dry steam per indicated horse-power per hour | 11.75 lb. | 11.52 lb. |
| Coal per indicated horse-power per hour actual | 1.02 lb. | 1.00 lb. |
| Coal per indicated horse-power per hour when feed pumps drawing from hot well and feed water = 280 deg. after passing economizer (calculated) | .99 lb. | .97 lb. |
| Coal per indicated horse-power on one week's trial of 56 hours, including banking of fires, during meal hours and at night | 1.29 lbs. | |

gram is 1.76″. The above distance, therefore, represents 0.077 of the stroke. To this is to be added the waste room, as assumed, 0.05 of the stroke, making in all 0.127 of the stroke = 9144 cubic feet of steam per hour saved by the compression. At the point of compression the pressure was 20 lbs. higher than at the point of release, or 81.7 lbs. on the square inch. At this pressure the weight of one cubic foot of steam is 0.19387 of a pound, and the weight of 9144 cubic feet is 1773 lbs. This, deducted from 11,340, leaves 9567 lbs. of steam per hour accounted for by the indicator, against 9343 lbs. of water supplied to the boilers. It will be observed that a greater weight of steam

by 28 per cent. is credited to the waste room than is charged to it. Therefore, if the amount of waste room was less than .05 of the piston displacement, then a still greater weight of steam was accounted for by the indicator.

An examination of the expansion curves on these diagrams reveals the fact, that, in order to raise the terminal pressures to the points shown by the indicator, by drawing the hyperbolic or Marriotte curve from the point of cut-off, not less than 0.16 of waste room must be added to the right hand diagram, and 0.12 of waste room to the left hand diagram. This shows that during the expansion there was a very unusual amount of evaporation of entrained water, and of water formed by condensation of the entering steam, and that, as would be expected, this amount was greater in the lower end of the vertical cylinder.

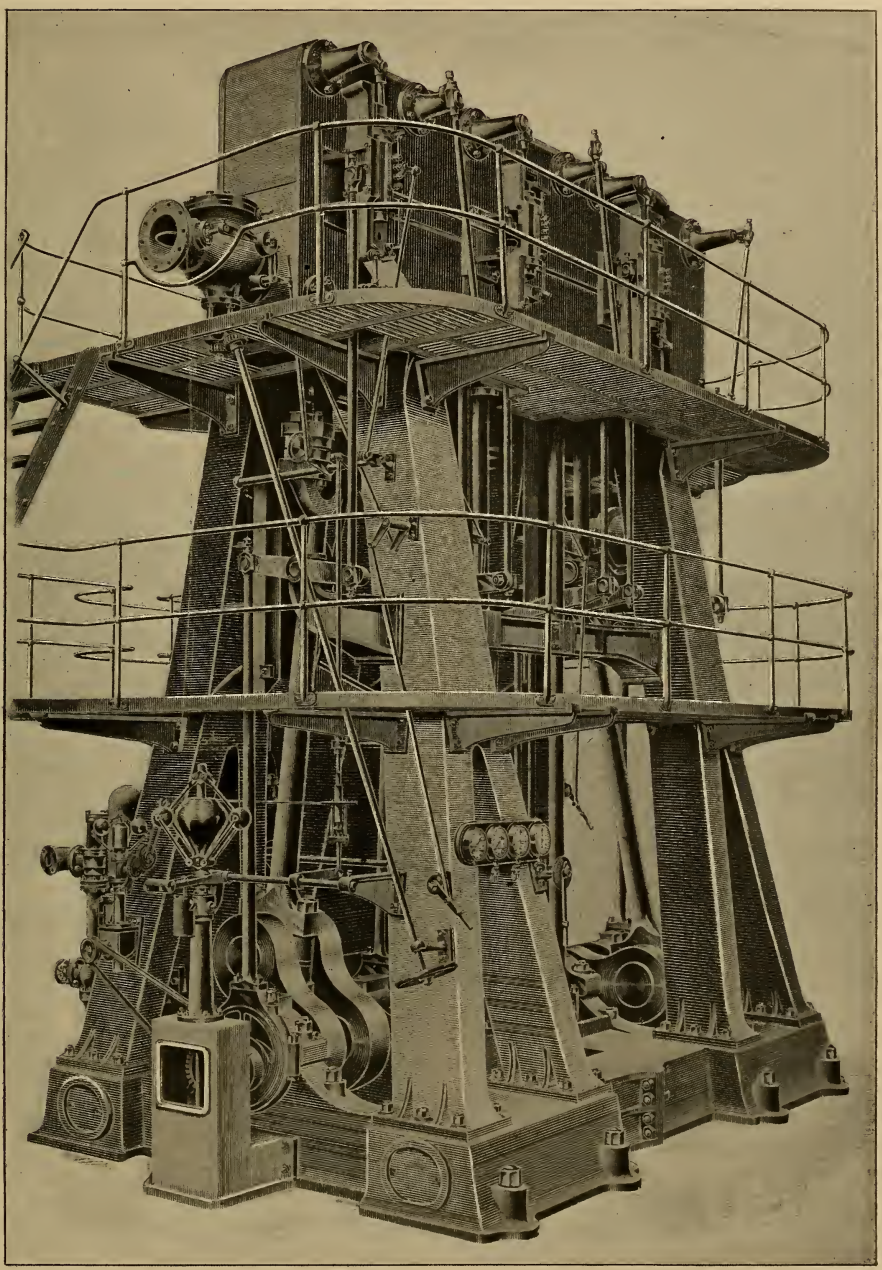
It will be interesting to observe the amount of this evaporation. For this purpose we will first examine the right hand diagram, in which the terminal pressure is 50 lbs. above the atmosphere. I have computed the theoretical terminal pressure from the highest point in the expansion curve at which it is certain that the steam had been cut off. This point is at 0.58″ from the end of the diagram. A length representing the 0.05 of waste room must be added to this, and also to the total length of the diagram. This length is 0.088″, making the length to the point of cut-off 0.668″, and to the point of release 1.848″. At the point of cut-off taken, the total steam pressure is 154 lbs., and so the total theoretical terminal pressure is 55.66 lbs. ($154 \times 0.668 \div 1.848 = 55.66$.) The atmosphere being deducted from this, leaves 41 lbs., or 9 lbs. less than the actual terminal pressure.

The left hand diagram, as has already been seen, is better than this. Here the terminal pressure is 44 lbs. above the atmosphere. The point of cut-off is taken at 0.53″ of the length of the diagram, which distance the addition of the waste room, 0.088″, increases to 0.618″. At this point the total steam pressure is 159 lbs. The total theoretical terminal pressure is, therefore, 53.2 lbs. ($159 \times .618 \div 1.848 = 53.2$.). The atmosphere being deducted from this, leaves 38.5 lbs., or 5.5 lbs. less than the actual terminal pressure The mean excess of the actual over the theoretical terminal pressures is thus seen to be 7.27 lbs. This excess, the reality of which any one can verify from the diagrams, makes the economy which appears to have been attained on this trial simply impossible; for not only is the water accounted for by the indicator in excess of that pumped into the boilers, but, moreover, I believe it to be the universal observation, that such an excess of terminal pressure in engines running at such a speed as this one, indicates not less than 20 per cent. of water not accounted for by the indicator, which is not yet re-evaporated, but which passes out with the exhaust.

The Marriotte curve, however, which we call the theoretical expansion curve, and employ as the reference curve, is, in fact, only used conventionally. It is so used for two reasons. It is a curve which is readily computed and plotted, and one to which it is found possible to bring the actual expansion curve, as drawn by the indicator, down, when the piston and valves are tight, only in cases of extremely economical performance, and below which, so far as I am aware, it has thus far been found impossible to get.

But in order to obtain a correct idea of what goes on in a cylinder during the expansion, it is necessary, instead of this curve, to draw the curve of specific volumes, which is the above curve as modified by the change in the temperature of the steam and other causes, and about the true form of which, it must be confessed, we are not certain, although the tables of specific volumes must be very nearly correct.

From the terminal pressure thus found we must deduct the steam that has been condensed by the conversion of its heat of vaporization into work. We shall then get the curve of no re-evaporation. The interval between this curve and the Marriotte curve represents the amount of re-evaporation



BY KIND PERMISSION OF ENGINEERING, LONDON.

ONE THOUSAND HORSE-POWER TRIPLE-EXPANSION ENGINE AT THE BROOKFIELD LINEN COMPANY'S MILL, BELFAST.

that must always take place, in order to bring the expansion curve up to what is commonly known as the theoretical, but which ought to be known as the conventional, curve ; and the distance of the actual expansion curve above which, and which distance in the cylinder under discussion is rarely exceeded, is found to be a pretty good index to the degree of wastefulness in the performance of an engine.

Our first inquiry then is:—What would be the mean theoretical terminal pressure in this cylinder, according to the method of specific volumes ? On the right hand diagram this terminal pressure is found to be 50 lbs., as follows :—The pressure at the point of cut-off taken is 154 lbs. The specific volume at this pressure is 183.3. This number being multiplied by 1.848, representing the actual volume at the point of release, and the product divided by 0.668, representing the actual volume at the point of cut-off, gives the specific volume at the point of release, which is 507. This corresponds to a terminal pressure of 50 lbs. By a similar computation, the theoretical terminal pressure in the left hand diagram is found to be 47.5 lbs. The mean of the two is 48.75 lbs., which is 5.68 lbs. lower than the mean terminal pressure given by the conventional curve.

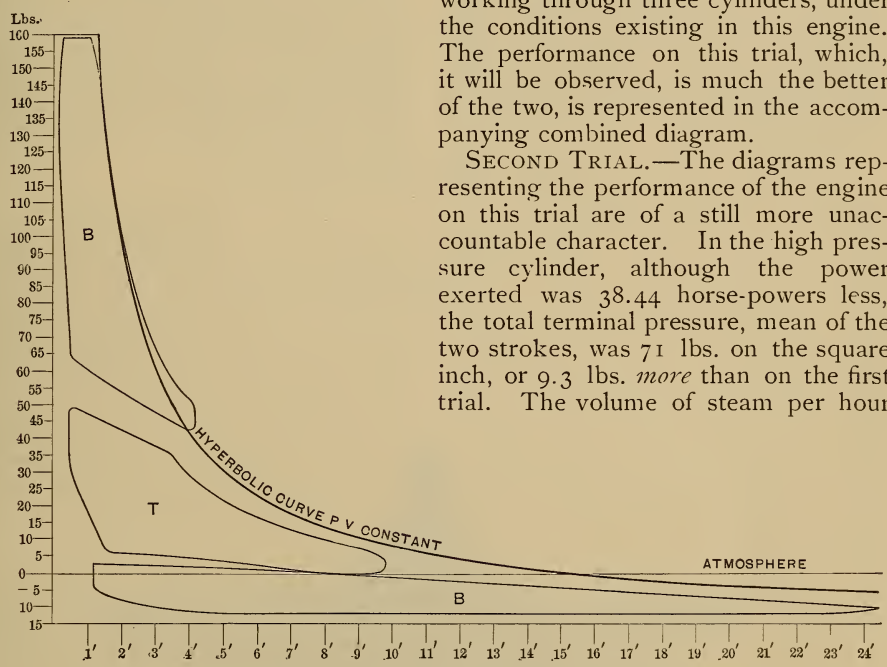
We have next to ascertain the amount of condensation that is produced by the conversion of heat into work. As the mean of both strokes, I find the work done on the expansion, in a single stroke, to be 74,140 foot-pounds. This is the total work, including that done in overcoming the counter-pressure. This requires the disappearance of 96 units of heat ($74,140 \div 772 = 96$). The proportion of the steam condensed to supply this heat is found as follows: The weight of the steam contained in the cylinder and waste room, at the point of release, or termination of the stroke, is 1.24 lbs., containing 929 units of heat of vaporization. Of the 96 units of heat converted into work, 25.5 units were supplied by heat set free on the expansion, leaving 70.5 units to be supplied by the condensation of 0.076 of the steam ($70.5 \div 929 = .076$), or of 3.705 lbs. This being deducted from 48.75 lbs., leaves a theoretical terminal pressure, if all re-evaporation be excluded, of 45.045 lbs.

This is 3.705 lbs. below the termination of the curve of specific volumes, and 9.385 lbs. below that of the Marriotte curve. The interval between this curve, terminating in a pressure of 45.045 lbs., and any curve described by the indicator, must always be filled by evaporation taking place during the expansion, and produced by heat supplied from the internal surfaces of the cylinder, heads, piston and passages, and from water present in the cylinder.

Let us inquire to what extent this is done by what may be termed legitimate evaporation,—that is, by the re-evaporation of water condensed in doing work. We have already seen that this condensation during the expansion caused a reduction of pressure of 3.705 lbs., representing 74,140 foot-pounds of work done. The work done before the cut-off was 59,660 foot-pounds, making a total of 133,800 foot-pounds. The re-evaporation, during the expansion, of the water condensed in doing all this work raised the pressure, in this case, by 6.686 lbs., or to a terminal pressure of 51.73 lbs., which is 2.7 lbs. below that shown by the Marriotte curve. All terminal pressure above this represented water existing in that form in the cylinder at the commencement of the stroke, or brought in with the steam before the cut-off.

The second and third cylinders will not occupy us long. In the second cylinder the initial pressure is 50 lbs. above the atmosphere, or 3 lbs. above the terminal pressure in the first cylinder. This is due to the compression in the intermediate chamber, as shown by the exhaust line of the preceding diagram. The pressure, however, falls rapidly. In order to ascertain the weight of steam used per hour in this cylinder, I have taken a point on the expansion curve, 0.5″ from the end of each diagram, and have measured the volume and pressure of the steam at this point, assuming 0.05 of waste room,

as before. The former is 121,600 cubic feet per hour. The latter, as the mean of the two diagrams, is 30 lbs. on the square inch. From the former I deduct the volume of steam, of the same pressure, that is saved by the compression. This is 17,000 cubic feet, which, being deducted from 121,600, leaves 104,600 cubic feet of steam, of 30 lbs. pressure, received from the first cylinder per hour. The weight of one cubic foot of steam at 30 lbs. pressure is 0.0775 of a pound, and, therefore,




COMBINED DIAGRAMS FROM THE ENGINES OF THE BROOKFIELD LINEN COMPANY.

104,600 cubic feet weigh 8100 lbs. *One thousand four hundred and sixty-seven lbs.* of steam have disappeared per hour between these two cylinders. It will be seen, that it makes no difference in the result, whether the amount of waste room is correctly assumed or not, it being charged and credited with the same weight of steam.

In the third cylinder the pressure at the same point of the stroke is 8.5 lbs. At this pressure the weight of one cubic foot of steam is 0.0227 of a pound. The volume per hour measured to this point, and not including the waste room, which is filled to this pressure by the compression, is just 300,000 cubic feet, and the weight of steam accounted for here by the indicator is 6800 lbs. Between the second and third cylinders 1300 lbs. more steam have disappeared per hour, making 2767 lbs. of steam lost per hour between the first and third cylinders. This is 30 per cent. of the water fed to the boilers, and is about the rate at which the steam would be expected to be condensed in working through three cylinders, under the conditions existing in this engine. The performance on this trial, which, it will be observed, is much the better of the two, is represented in the accompanying combined diagram.

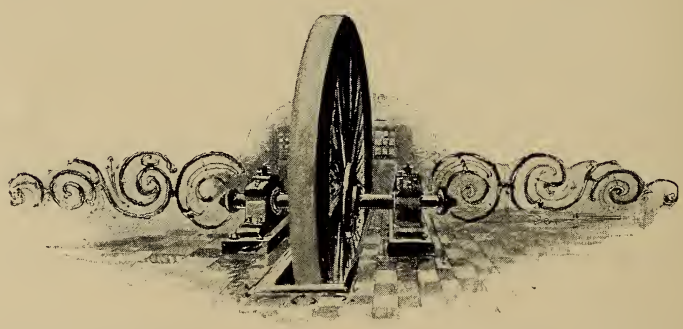
SECOND TRIAL.—The diagrams representing the performance of the engine on this trial are of a still more unaccountable character. In the high pressure cylinder, although the power exerted was 38.44 horse-powers less, the total terminal pressure, mean of the two strokes, was 71 lbs. on the square inch, or 9.3 lbs. *more* than on the first trial. The volume of steam per hour was the same, namely, 75,600 — 9144 = 66,456 cubic feet. The weight of one cubic foot of steam at 71 lbs. pressure is 0.17038 of a pound, and that of 66,144 cubic feet is, thus, 11,320 lbs. Here are certainly 1753 lbs. of water accounted for by the indicator more than on the first trial, but the weight of water supplied to the boilers was 237 lbs. less. The indicator accounts for 11,320 lbs. of steam, and 9106 lbs. of water were pumped into the boilers!

The diagrams taken from the second cylinder exhibit a surprising phenom-

enon. They are drawn to the same scale as those from the same cylinder on the first trial. Each of these pairs of diagrams intersect one another almost exactly at the middle of their length. On this trial the initial pressure obtained in this cylinder was 12 lbs. higher than on the first trial, being 62 lbs. above the atmosphere, in place of 50 lbs., corresponding to the higher terminal pressure in the first cylinder. But it fell so much more rapidly, that at the point of intersection of the diagrams it was only 1 lb. higher, being 41 lbs. total pressure, that on the first trial being 40 lbs. The indicator accounts, therefore, for only 0.025 more steam in this cylinder than on the first trial, or for 8300 lbs.

According to these diagrams, 3020 lbs. of steam disappeared between these two cylinders per hour. The diagrams from the low pressure cylinder show ¾ of a pound more pressure at the mid-stroke than on the first trial, and so account for 0.05 more steam, while the water evaporated was less.

I shall not attempt a solution of the puzzles here presented, but I must congratulate the builders of this engine on the engineering skill that has enabled them to escape from the penalty, on a guarantee of a twelve-pound duty. As for the record claimed, of 11.52 lbs., that cannot be allowed to stand. Every engineer of experience knows perfectly well, that an engine giving diagrams such as these is not capable of running with this economy, nor with any that approaches it.



# TOWN REFUSE FOR STEAM RAISING.

*By T. W. Baker, B. A.*

THE disposal of ashbin refuse and street-sweepings in large towns has been a source of considerable trouble and expense to the local authorities, and several vestries in London are now paying 3s. per ton for its disposal, exclusive of the expense of collecting it. Consequently if 70 per cent. can be utilized and barging saved, considerable economy must ensue. There appears at the present time no doubt whatever that ordinary ashbin and street refuse should be dealt with by fire at the earliest moment and at the nearest possible point, as it soon becomes a prolific source of zymotic diseases. Consequently prompt and localized destruction is particularly desirable, as railway conveyance or barging causes delay and contamination to the surrounding atmosphere.

In order to better understand what ashbin contents consist of, the author, in a paper recently read before the Society of Engineers, and from which what is here given has been substantially reproduced, appended the following analysis of Mr. Joseph Russell, given in a paper read some time ago before the Sanitary Institute. This may be of interest, having been practically corroborated by several other authorities.

ANALYSIS OF ASHBIN REFUSE.

| Component parts. | Average per 1,000 loads. Tons. | cwt. | qr. | lb. | Percentages of weight. |
|---|---|---|---|---|---|
| Breeze, cinder and ashes | 611 | 3 | 0 | 4 | 63.69 |
| Fine dust | 187 | 1 | 9 | 8 | 19.51 |
| Vegetable, animal and various mineral matters | 44 | 3 | 3 | 20 | 4.61 |
| Waste paper | 41 | 1 | 1 | 20 | 4.28 |
| Straw and fibrous material | 30 | 18 | 1 | 6 | 3.22 |
| Bottles (5,000) | .. | .. | .. | .. | 0.96 |
| Coal and coke | 8 | 0 | 2 | 14 | 0.84 |
| Tins | 7 | 11 | 2 | 22 | 0 79 |
| Crockery | 5 | 5 | 0 | 0 | 0.55 |
| Bones | 4 | 12 | 1 | 1 | 0.48 |
| Broken glass | 4 | 11 | 2 | 2 | 0.47 |
| Rags | 3 | 15 | 3 | 16 | 0.39 |
| Iron | 2 | 0 | 0 | 20 | 0.21 |
| | | | | | 100.00 |

From the report of the London County Council on dust destructors, the average from several districts gives 260 tons per annum for one thousand of the population, although the actual quantities vary widely. Taking this

T. Wm. Baker, after taking his degree at Cambridge University, acquired an extensive engineering experience, following various lines of professional work, until, in 1884, he established himself at London as consulting engineer. His first electric lighting experience was in 1878, and subsequently he was called in by the City of London Union as their adviser among other public authorities. In 1892 the question of the disposal of town refuse came prominently before him, and led him to carefully study the subject. One outcome of this was a paper on the steam-raising value of town refuse, read before the Society of Engineers, in which he dwelt upon the clearly apparent necessity of better means of destruction and utilisation of such refuse, and for which he was awarded a gold medal and the president's prize Mr. Baker is a Bachelor of Arts an associate member of the Institution of Civil Engineers, and also a member of the Society of Engineers.

into consideration, and the fact of the preponderant amount of combustible material which it will be noticed is present in this refuse, it is apparent that it should be disposed of by fire not merely with a view to its destruction for hygienic reasons, nor yet to reduce its bulk —which is done by the destructors in present use, leaving only from 25 to 30 per cent. of ash and clinkers—but that the heat set free in the process of destruction should be utilized.

Professor Forbes and others have estimated the value of ashbin refuse at a much higher figure than results from practice, the various estimates ranging from 3 lbs. to 5 lbs. of water evaporated for 1 lb. of refuse. Hitherto in practice this result has not been obtained, and according to statistics collected by Mr. C. Jones, M. I. C. E., from the larger towns using destructors with steam generators by the waste heat, 6-horse-power per cell burning from six to eight tons every twenty-four hours appears to be the average result. This result, doubtless, can be increased by the use of forced draught, at the same time enabling the furnaces to do a far greater amount of work as destructors.

These statistics, no doubt, include the disposals of the street sweepings, which must be taken carefully into account, they being the vehicle for moisture impregnated with effluvia, which, during destruction, absorbs some of the active heat from the more combustible ashbin refuse. As the various local authorities, particularly around London, are now anxious to use their powers under the Electric Lighting Provisional Orders granted to them for laying down plant for lighting their districts by electricity, this appears to be the better and most direct method of using this source of gratuitous heat. At the same time there are water-works and sewage pumping stations requiring steam, as well as baths and wash-houses which frequently belong to the local authorities, where the heat could be advantageously utilized.

There can be doubt that the calorific value of the refuse is low, particularly when street sludge is used, and from results obtained by the author, only 1 lb. of water evaporated per pound of unsifted refuse is actually obtained. With screened refuse, however, that is, with the paper and loose rubbish, commonly called breeze, taken out, a fair average of 2½ lbs. of water evaporated per pound of breeze is the result. For some months past the author has been using this fuel in an ordinary double-flued Galloway boiler, 22 ft. long, 7 ft. diameter, with twenty-two cross tubes and steam jet forced draught, the boiler being used for boiling purposes. These results could only be obtained by burning the breeze in direct contact with the boiler, and could not be so obtained if used in a destructor and then passed through brick flues to the boilers; Mr. Jones' statistics before referred to are based upon the working of plants of the latter description.

The trouble in stoking, owing to the amount of ashes and clinkers, prohibits the general use of town refuse in boiler furnaces to any great extent. A very large boiler capacity and great area, proportionate to the quantity of steam required, are necessary, far beyond that usually required for ordinary coal burning, and further, unless the refuse is mixed with coal, 60 lbs. appears to be the maximum boiler pressure obtainable. Even with a strong forced draught in the ashpit, 80 lbs. only has been obtained. Consequently to make the use of the town refuse economical, in connection with the best modern steam engine practice, a greater heat must be available and a higher pressure attained. Moreover, in thickly populated districts all escaping vapors must be rendered innocuous, so that there are three conditions for consideration, namely :—(1) Facilities for stoking and cleaning the fires. (2) Burning up the obnoxious fumes. (3) Temperature of combustion to be raised to produce higher pressures. First as regards facilities for stoking and cleaning the fires. The principal of the ordinary dust destructor in its general design is doubtless the best, viz.: Having the feeding hopper at the upper end and the fire-bars at a lower level continuing toward the cleaning doors, and having

mechanically moved fire-bars bringing the refuse forward, allowing the green fuel to be gradually brought toward the fire, thus evaporating and burning up the moisture in it. Of the several designs of different makers, that known as Healey's appears to be a good type, and most advantageous when used with a forced air draught, although there are several other designs which are equally applicable, viz., Fryer's, Horsfall's, Wiley's and Warner's.

In Healey's furnaces the hearth plate is at an upper level, on which the refuse is fed, and which in its descent travels on to a movable gridiron and from thence to the fire-bars proper. In order to keep the furnace at its full work, this continual feed is necessary; but Healey's movement of the furnace bars has the triple effect of feeding the furnace and clearing the clinkers off the bars and pushing them into a receptacle for removal. This is accomplished by resting the front of the fire-bars on the dead plate, the back bearer being a rotating cam-shaft with eccentrics, on which is fitted each alternate bar, which has a slot fitting these eccentric cams on their undersides. The other alternate bars are fixed to a bearer and in a recess on the front dead plate. On their upper edge another bar is fitted with a parallel ball-and-socket joint. The upper ends of these bars oscillate in a recess in the upper hearth plate. The fronts of the fire-bars also oscillate on the front dead plate, so that on the bearer shaft being rotated toward the front, the movable bars lift the clinkers and fuel forward off the fixed bars and a constantly clean fire is kept. At the same time new fuel is fed from the upper hearth plate. The shaft is rotated by a ratchet wheel worked by an eccentric from a rotating shaft at the furnace front, driven by the forced draught blast engine. The air blast is brought from a conduit under the ashpits by pipes on either side and opposite each other, in the fore part of the ashpits. Special facilities are provided for clearing away the dust from the flues at all possible points, and a dust-settling flue or chamber is also provided between the furnaces and the chimney, which is preferably on the back of the furnaces.

Hitherto the practice as regards the generation of steam has been to place a tubulous steam boiler between the destructors and the chimney, leaving the walls of the flues to absorb a large quantity of the heat before reaching the boiler. Between the destructor and the boiler a Jones' fume creator is frequently used, which consists of coke furnaces so constructed and arranged that the flues from the destructors conduct the gases over these fires by deflecting masonry, thus cremating them and rendering them innocuous by destroying the excess of moisture and effluvia which would otherwise escape as noxious vapor and condense in the atmosphere, and cause what has been recently described as an unmitigated nuisance.

At Cambridge, Messrs. Wood & Brodie's system of furnace is being adopted. It consists of a water-tube Babcock type steam generator placed in series between every two refuse furnaces. The waste gases are conducted through brick flues into a chamber under a V-shaped ash-tray or pit, and then over its upper edges through the fire-grate to the water-tubes and ordinary setting of the generators.

At Warrington a special refuse furnace has been erected in front of the furnace of a Babcock steam generator, the place of which it takes. It is fitted with forced draught, the refuse fuel being conducted by hoppers from the floor above to the furnace. From the results which Messrs. Babcock & Wilcox have kindly supplied, it appears that in this case 1.14 lbs. of water were evaporated per pound of unscreened refuse from a temperature of feed of 104 degrees Fahr., into steam at 66 lbs. pressure.

From the author's experience, the system which recommends itself is that of placing a steam generator directly over the destructor furnace, so that the heat shall pass around or impinge directly on the heating surface of the generator. The ordinary generator furnaces are placed above the refuse furnace,

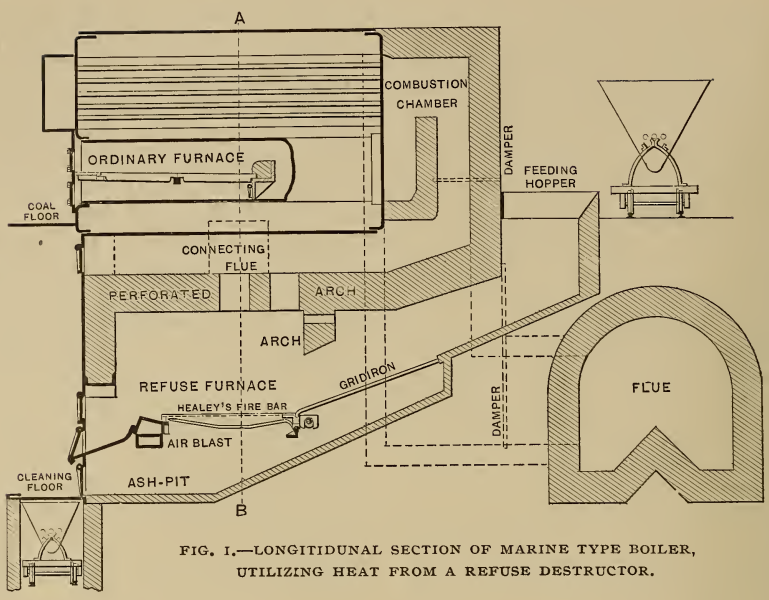



FIG. I.—LONGITIDUNAL SECTION OF MARINE TYPE BOILER, UTILIZING HEAT FROM A REFUSE DESTRUCTOR.

and are used as supplementary furnaces to increase the temperature necessary for the higher pressure demanded, and also to cremate any obnoxious gases from the refuse furnace below. Where destructors are in use, and it is desired to utilize the heat from them to generate steam at high pressures, the generators may be arranged in a series adjoining the main flue to the chimney, and by connections the gases may be directed into their combustion chambers, and so utilized and cremated. Where it is practicable, however, to place the generators over the existing lower furnaces or destructors, it is greatly to be preferred as being more effective.

There is no doubt that the gases from refuse are impregnated with a large percentage of moisture, and are of low temperature. This is shown by an analysis of the gases, where a preponderating amount of nitrogen is found, amounting to 22 per cent., and any contact with the side walls of brick flues has the effect of impairing the efficiency, the walls being always ready to absorb some of the moist heat, the surfaces necessarily having to be large. With these considerations it will be seen that to obtain the best effect the radiated heat must be absorbed directly by and transmitted to the generator. This is accomplished by placing a reverberatory perforated fire-brick arch over the refuse furnace, with the generator above it, so that when an excess of green fuel comes down from the hearth-plate, the regenerative heat from the arch assists to cremate the fumes before passing to the upper furnace.

There is no doubt that hand sorting of ashbin refuse will be largely discontinued on account of its degrading nature, and also from the decreasing prices of bones, rags, waste paper, etc., making it less profitable than formerly. There will therefore be a proportionately greater quantity of animal matter to be disposed of, and the consequent effluvia must be constantly dealt with, so that the need of an effectual fume cremator is absolutely necessary. These fumes it is proposed to cremate and destroy, with the assistance of the reverberatory arch, by the higher temperature of the combustion chambers of the ordinary and supplemental furnaces of the generators, this being their hottest part, the temperature of which will be never less than 1500 deg. Fah. It has been found that to effectually destroy refuse fumes, 1250 deg. Fah. is

absolutely necessary, and it would appear almost impossible for any effluvia to escape after passing through these two heats. Means must also be provided for the admission of fresh oxygen into the combustion chambers if necessary to complete combustion; the gases or fumes from the destructors might also be burnt through the furnace bars of the supplementary furnaces if desired, when oil or producer gas is used as fuel.

The author has recently had some experience of the effect of escaping effluvia when saturated with moisture. It was proved in a recent law case that persons in close proximity to the 60 ft. chimney shaft, from whence it was alleged the foul gases were escaping, scarcely complained, but numerous complaints arose from those from 300 to 1000 yards distant, showing that it took that distance to bring the saturated effluvia to earth. In some existing plants in which no utilisation is attempted, the cost of fuel for the crematory fires has been so great that they have been discontinued, but serious complaints from the neighbourhoods are now arising, thus showing the advantages of cremation.

The calorific value of refuse being low, it is necessary to provide ordinary generator furnaces to assist in raising the steam to the required pressure, for economical use as well as for cremating, as in several of the existing plants with the boilers in the flues, 40 lbs. pressure per square inch is all that can be obtained, and at Warrington 68 lbs. only is obtained even with forced draught. In the ordinary furnaces of the generator, good fuel should be used, and if a supply of Russian oil can be obtained, that, or producer gas, appears to be especially applicable.

Having now described the general principles of the generation and absorption of the heat by the generator, and having specially in view the use of the steam generated by it for electric light stations, viz., to assimilate the supply to the demand, the author will deal with the question from the latter point of view. It is well known that the demand of electricity during the day is so light, even where a fairly high load factor is obtained, that the use of the steam generating plant at even half its capacity would be an excess, so that a system of heat storage is necessary for the economical use of the refuse, as

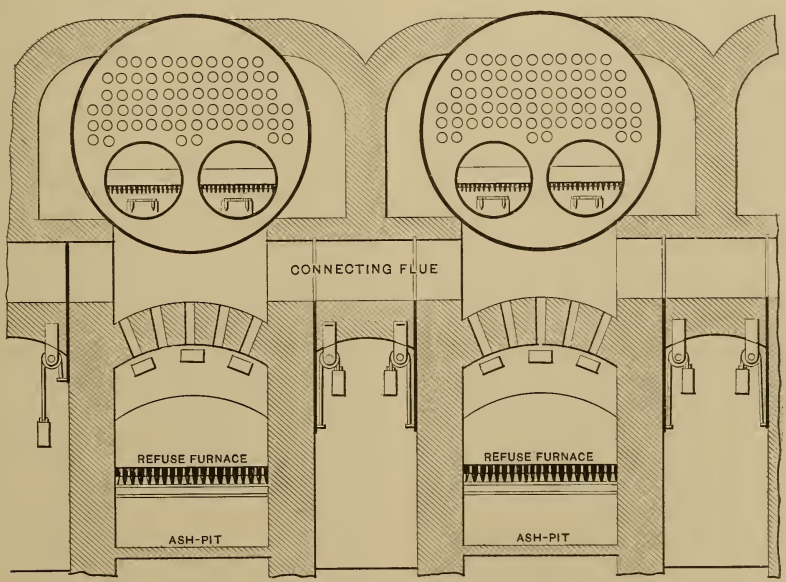



FIG. 2.—CROSS SECTION.

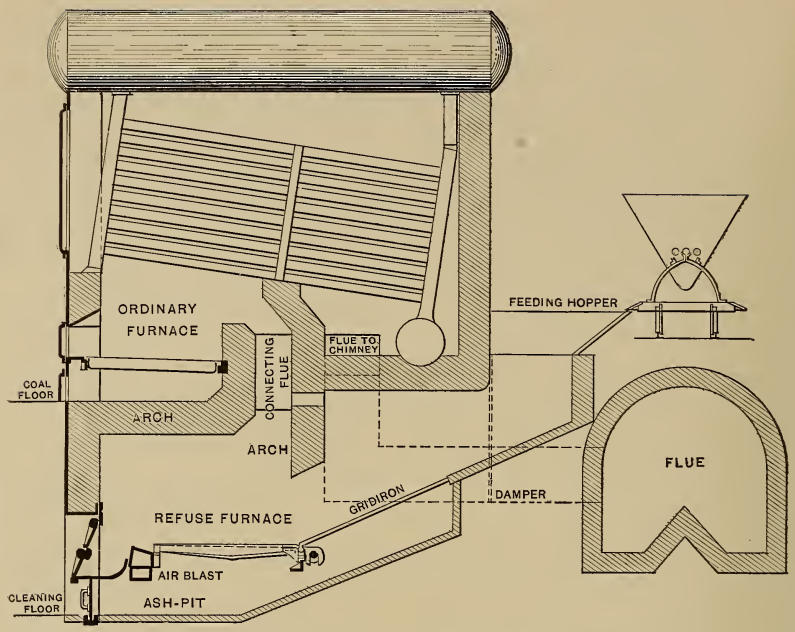



FIG. 3.—WATER TUBE BOILER WITH REFUSE DESTRUCTOR SETTING.

the destructors must always be at work. Any ordinary form of steam generator may be adopted, but the cylindrical dry back marine boiler with two flues, or the inclined water tube boiler of the Babcock and Wilcox type, are best suited. They are illustrated at Figs. 1, 2 and 3, and they are so well known as to need no further description. Fig. 2 is a section showing the method of connecting the refuse furnaces to either steam generator. Lancashire boilers, on account of their length, are not well suited to the present purpose, as the temperature of the gases in the combustion chambers frequently falls below 1250 Fah., and allows the moisture to pass away undecomposed. In all cases the refuse gases are conducted into the combustion chambers or their hottest part, while in the marine form they are led to the space above the flues and opposite the tubes, the gases from the ordinary and crematory furnaces of higher temperature mixing with them. In the water-tube generators they enter the ordinary furnace from behind the furnace back, in both cases meeting with the partly incandescent fire-brick masonry, which assists in evaporating any moisture and destroying the effluvia. It is also necessary to keep the generators short, otherwise the feeding floors must be placed over the boilers, with descending hoppers. This design also takes up more ground area for the inclined roadway, the other forms being conspicuous for the small space occupied by them.

Referring to the refuse destructor and steam generator combined, for dealing with 420 tons of refuse per week—which is an average quantity from several London vestries—some six or eight sets would be required for electric lighting purposes. These would be in one battery adjoining each other, the flues between the arches over the refuse furnaces, and under the generators, would communicate with each other, so that any number of refuse furnaces might be coupled to one generator and its crematory furnace. For the day load, however, they should be worked in sets of three, so that the middle generator alone would have its ordinary furnace in use, the refuse furnaces below all communicating with the one

generator by dampers being opened between them and other dampers closing the two outer generators from the chimney flue. It will thus be seen that the two outer generators would be kept at the same working pressure as the middle one, and would always be available by their own furnaces being brought into use, so that the stand-by losses would be wholly taken up by the refuse. There would also be an excess of steam, during the extreme light loads, which should be stored in the following manner :

A tank or reservoir properly clothed to prevent radiation is to be placed as a roof to the boiler house, and in this tank, near the bottom, is fitted a coil of pipes. The waste steam would be taken into this coil, which is immersed in water, thus condensing the steam, and ejecting the condensed water into the tank itself, eventually filling it with practically distilled hot water every day, and this would be the case either with condensing or non-condensing engines ; but when condensing engines are used it will be preferable to filter the condensed water from the air pumps, and use this as feed-water through the boilers, and thence into the storage tanks, as before described ; but where non-condensing engines are used it would be better to allow the waste steam in the coil to heat up and boil the water in the storage tanks, in which would be deposited most of the impurities, the coil being connected by a system of steam flow and water return to the generators. Under these circumstances a live steam feed-water heater and separator would be necessary to feed the generators during the light load, bringing into use the boiled storage water during the heavy demand for steam.

This may be explained by reference to the diagram, Fig. 4, showing the steam generator and heat storage tank and their connections. A is the steam main supply pipe connecting the generators with the engines, etc., from the main by means of an automatic balanced steam valve B, allowing the escape of any excess steam over that required for the immediate requirements of the engines ; this is connected with a coil of condenser tubes C, placed at the bottom of the storage tanks, the outlet from this coil being at D, which is connected again to the steam generator through the return valve E. The action of this apparatus will be apparent, the excess of waste steam being conducted through the coil, which is immersed in the water in the tank—if used with a non-condensing plant—containing the original impurities inherent from its source ; thus steam heat

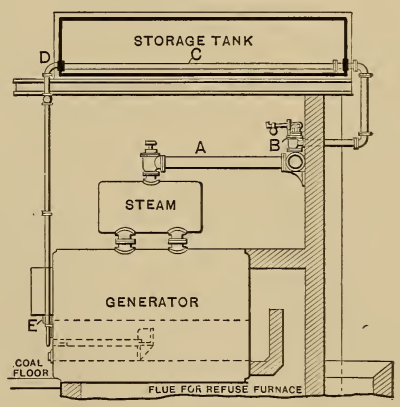



FIG. 4.—BOILER AND HEAT STORAGE TANK.

will then be transferred to the volume of water, as previously stated, of 20,000 gallons, preferably in four tanks or reservoirs, the condensed water returning by the pipes and valve E to the generator. Where carbonate and sulphate of lime is present in the feed-water, and with a non-condensing plant, it will be precipitated in the storage tanks, the live steam feed-water heating up the water to 300 deg. Fah., setting up the separation on its entering the tank and afterwards settling in it, means being provided for preventing its settling on the coil, so that practically pure hot water will be provided for use without any pumping under pressure. In condensing plants, the feed-water having been filtered in coming from the air pump, it may be condensed and ejected into the storage tanks through the generators, having been previously puri-

fied, or directly into the tanks, and there reheated as in non-condensing plants. It must also be observed that any generators not actually in use for the day load will also be additional storage reservoirs.

When multitubular generators are used, care must be taken that increased internal tube area is afforded for the passing of the gases from the three refuse and crematory furnaces. This system can be applied to existing destructors, as water-tube generators may be made of a width to suit such circumstances, where probably cylindrical boilers could not be so placed. The net result of this system would probably be, that ¾ lb. of water would be evaporated by 1 lb. of refuse, allowing for the lesser value of street sweepings or sludge, and the absorption of a certain quantity of heat in the furnace masonry, as compared with the 1 lb. of water per 1 lb. of refuse which has actually been accomplished—as before explained—a result which is corroborated by Mr. A. Collins, A.M.I.C.E., of Reading, and the Warrington tests in directly-fired generators. Reducing this to financial terms, the saving in barging, which has been mentioned as the only credit, must be first considered. This, according to the average cost per ton to several of the London vestries, amounts to 3s. per ton after collection, and 70 per cent. can be utilized, leaving only 30 per cent. of ash and clinkers as a residue to be disposed of, which in the spring is readily marketable for road-making, and where crushing machinery is in use it can be prepared for mortar, and with cement manufactured into street paving. This source of profit will, however, be absorbed by the cartage on the unsold residue, also by the fuel account for the generator furnaces, for working the forced draft and moving the furnace bars, the net saving being therefore the cost of barging or disposal of 70 per cent. at 3s. per ton; and, taking six furnaces burning ten tons each every twenty-four hours, equal to the consumption of 420 tons per week of seven days—294 tons at 3s. will represent the saving in barging, amounting to £44 per week, or £2288 per annum. The gross credit will be the value of the steam generated from the refuse. As each furnace will be of a capacity to burn ten tons every twenty-four hours, and taking 20 lbs. of steam per indicated horse-power per hour, and non-condensing engines without the cremating fires, the effective evaporation will be equal to 35 indicated horse-power per hour per generator set and available for electric lighting. From the returns of the various London electric lighting plants 1d. per unit appears to be a fair average for the cost of coal. Six destructors and generators would give an hourly output of 210 indicated horse-power from refuse only, or allowing 15 per cent. for frictional loss = 177 electrical horse-power, which at 1.34 horse-power per unit = 128 units at 1d., or 11s. 1d. per hour, say £93 1s. 6d. per week, against which the extra cost of maintenance, wear and tear have to be debited. If ashbin refuse alone were burnt the results would be 15 per cent. to 20 per cent. in excess of this, and this result could only be attained if the steam were used by the engine as generated, but against this, and as a general debit, the inherent losses of storing the heat and the reheating will have to be considered. As this process will be going on for two-thirds of each twenty-four hours, the author estimates this loss at 30 per cent., but being sixteen hours only out of the twenty-four = 20 per cent. on the total 35 indicated horse-power, leaving a net effective result—after deducting 15 per cent. for frictional losses—of 23.6 electrical horse-power per hour per set, which may be absolutely depended upon. The total value at 1.34 horse-power per unit equals 1s. 5½d. per hour per set, or 8s. 9d. per hour for the six sets; that is £73 10s. per week, or, per annum, £3822; less £350 for steam for auxiliary blast and grate engines and pumps, £350; total £3472.

Mr. G. Watson, C. E., of Leeds, in a paper read before the British Association, in 1892, gives the theoretical value of ashbin refuse as 1 lb. evaporating 2.13

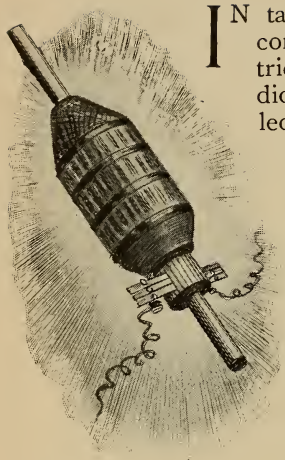
lbs. of water and the practical result at 1d. per indicated horse-power per hour with a steam generating plant of improved type, or 1s. 3d. per cell per hour, burning 5 cwt. of refuse at a total cost of 1s. 10d. per ton. At Oldham, some authorities give the cost at 1s 6d. per ton, including all expenses and depreciation. Taking these figures and the evaporative tests of the author, of Mr. Collins and those from Warrington, the foregoing figures may be considered fairly substantiated, together with the results deducible therefrom. The ordinary or supplementary furnace heat is not considered in these estimates, as that would be directly available for extra evaporation at proportionately increased returns. The author considers, as previously stated, that a plant capable of dealing with 420 tons of refuse per week would be of suitable working capacity for a London vestry. The plant would consist of eight refuse furnaces—two in reserve—with six steam generators for 140 lbs. working pressure with feeding, coal and cleaning floors, forced draught, machinery, movable fire-bars, storage tanks and chimney, and capable of a total output of 900 brake or electrical horse-power when fully loaded. The author estimates the cost, including £3000 for the site, at £18,000.

The maximum indicated horse-power from the refuse only is computed at 48 horse-power per cell, the extra evaporation by the supplementary furnaces at high load utilsiing the remainder of the heated feed-water out of a total of 25,000 gallons. The quality of ashbin refuse varies greatly. During the summer it is generally very poor, but from the better districts of London it may be advisable to sift it over a shoot during early spring, reserving the better fuel, which it will be found to contain, for use in the ordinary furnaces during the summer, and thus increasing the economy. From inquiries the author finds that the refuse from some localities would not repay this necessary outlay. The author's experience is that the Paddington siftings have been fully 25 per cent. less in value in July than in March, which has caused a lower evaporative average value to be given than the individual tests before referred to by others, as on individual weeks from January to March the breeze was particularly good, as shown by water and quantity tests.

The author has endeavored to place the complex question of the disposal of town refuse in a practical light. The obtaining of the facts has been the outcome of the necessity of obtaining a cheap fuel for slow steaming, and of utilising refuse for producing electricity. The author's experience in connection with electric lighting since 1878, particularly when required for factories, is that would-be users first ask themselves—"Have I engine or boiler power to spare?" The idea of a separate plant, using a waste product, has been, until the past few years, quite foreign to the question. It now, however, may be said to solve an important problem. It will probably be admitted from what has been stated, that in addition to meeting sanitary and hygienic requirements, this system of refuse utilization constitutes a valuable source of profit, to which public authorities are at length becoming alive.

# THE ELECTRIC MOTOR.

*By Prof. F. B. Crocker.*



IN taking up the historical consideration of the electric motor, as the writer did, some time ago, in a lecture before the Franklin Institute, we have the amber of the ancients as the first electric generator, corresponding to the dynamo, and its attraction of feathers and other light bodies as the first artificial production of motion by electricity, corresponding to the electric motor,—artificial, because lightning has from the beginning of the world caused powerful movements and disturbances in the bodies which it strikes. Thus the birth of these two important machines was simultaneous ; indeed, electricity was discovered solely by the fact that it produced motion under conditions which were peculiar, and it seemed to be so different from all other natural phenomena that from those early times, even up to the present day, it is looked upon as the most wonderful and mysterious agency in nature.

The magnetic attraction of pieces of iron by the lodestone was also observed by the ancients, and the electric motor of the present day is more directly based upon this phenomenon than upon the electrostatic attraction caused by amber.

From those early times up to the present century, particularly during the last century, numerous experiments were made with magnetic and electrostatic attraction, but no one produced any results which can be considered to be any more like an electric motor than the simple experiments of the ancients. The first apparatus which in principle and construction sufficiently resembled the machines of to-day, to be properly regarded as an electric motor, was Barlow's wheel, described by him in his work on "Magnetic Attraction," published in London in 1823. This invention is remarkable in the fact that it antedated by eight years the disc machine of Faraday (which was the prototype of the dynamo), and his discovery of magneto-electric induction in 1831. Not only was Barlow's wheel far ahead of Faraday's disc in point of time, but it was also a much better construction, because the former was made in the shape of a star with long points so that the current was confined to the particular portion of the wheel which was between the poles of the magnet. In Faraday's disc, on the other hand, the current produced in that part of the disc actually between the poles was at liberty to flow back through all the rest of the wheel. The armature was, therefore, completely short-circuited in itself, a feature which we know to be one of the worst faults that it can possibly have, and the amount of current obtained in the external circuit was an almost infinitesimal fraction of that produced, being only sufficient to deflect a galvanometer needle. It was, indeed, a fortunate thing for science that any perceptible effect whatever was ob-

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tained, otherwise the most important discovery of the nineteenth century might have been delayed.

Joseph Henry, in 1831, was the first to construct a motor which worked by electro-magnetic attraction. This apparatus really has a better right to the distinction of being called the first electric motor than Barlow's wheel. Many other inventors followed Henry in devising forms of electro-magnetic motors. Jacobi in 1834, Davenport in 1837 and Page in 1838, are particularly worthy of mention. Some of these early motors were by no means mere toys, but were of considerable size and power. Jacobi, of St. Petersburg, in 1838, propelled a boat twenty-eight feet long at a speed of three miles an hour; and Page, of Washington, in 1851, succeeded in obtaining a speed of nineteen miles per hour with a car carrying a number of persons and driven by a sixteen horse-power electric motor. This result, by the way, is practically the same as that obtained from the most improved trolley cars of to-day, both in speed and power.

This brief glance at the early history of the electric motor brings out the striking fact that this machine was invented eight years before the dynamo and for several decades it was considered of more importance, both scientifically and practically, the motors of Jacobi and Page, for example, being far more powerful than any contemporaneous dynamo. A search through the patent records of the United States and England would show also that more attention and greater expectations were then based upon the motor. This was undoubtedly due to the fact that inventors hoped to obtain a source of power which would rival or surpass the steam engine. It was gradually realized, however, that the cost of electrical energy obtained from a primary battery is so high that it cannot compete with a steam engine. The number of pounds of zinc consumed in the best battery, per horse-power hour, is about equal to the weight of coal required to give the same amount of energy in a steam engine; and since zinc costs about fifty times as much per pound as coal (in fact it actually requires several pounds of coal to produce one pound of zinc), it is obvious that the primary battery is far more costly than steam in the generation of power. As a matter of fact, electrical energy from a primary battery at the present time costs at least ten times and probably twenty times as much as that obtained by the use of a steam engine and dynamo.

The realization of this serious difficulty greatly discouraged scientific men and inventors in regard to the electric motor. A reaction set in against it, and for many years it was comparatively neglected by the best workers. The dynamo was taken up in its stead and developed in the remarkably rapid and successful manner which is the greatest practical achievement of recent times. The neglect of the electric motor continued until about 1887, the dynamo having by that time reached a state of great perfection and being in extensive use for electric lighting. The development of the dynamo, and the laying of electric light circuits through the streets of many cities and towns, provided the very supply of reasonably cheap current which was needed for the motor, and which the primary battery had failed to give.

This fact encouraged inventors and manufacturers to again take up the motor, and since that time its progress has been very rapid; but even now the motor is somewhat overshadowed by the dynamo. In the United States there are about 100,000 stationary motors and several thousand railway motors, but in the whole of Europe the number is not much more than one-tenth of these figures. This last fact probably explains why the literature of the dynamo is much more complete than that of the motor, since most of the books are written by Europeans—the time of Americans being occupied rather with making and using dynamos and motors than with telling others how to do these things. The most recent history of the motor includes the invention by Tesla, in 1888, of the two-phase alternating current motor and

the development of the two and three-phase systems. These important systems are now being practically used, and an enormous electric power transmission plant is being installed at Niagara Falls, which is to be operated by the two-phase system. Indeed, it may be said that the progress of the electric motor at the present time is equally as rapid as, and more interesting than, that of the dynamo.

If the dream of the electrical engineer should be realized and electrical energy could be obtained directly from coal, without the use of the steam engine and dynamo, then the importance of the electric motor would be paramount, and it would be used in practically every case where power is needed.

The points in the history of the electric motor to which I desire to call particular attention are these, that for many years it was considered of greater importance than the dynamo; that it then fell into a position of comparative insignificance, but that in the last few years it has again become very prominent, and in the future it is certain to be of still greater importance, while the dynamo may become obsolete.

In considering the construction and action of the electric motor, the first and most important fact is its great similarity to the dynamo, or, more strictly speaking, it is practically the same machine used in exactly the opposite manner. The dynamo is a machine which generates electric current when driven by mechanical power. A motor is a machine that develops mechanical power when supplied with electric current; thus the functions of the two machines are exactly the converse of each other; nevertheless, identically the same machine can be used for either purpose, that is to say, the machine is perfectly reversible. It is also a fact that a machine that is good for one purpose is good for the other. The old idea that a good dynamo was not necessarily a good motor, and that considerable differences in construction are required, is, so far as the writer's experience goes, a fallacious one. The tendency is now for manufacturers to make exactly the same machine and use it for either purpose indiscriminately with only very slight differences in the details of winding, connections, etc.

While it is true that the two machines are practically identical in construction, nevertheless their actions are somewhat different, and this difference is just sufficient to be puzzling. It seems to be a fact that knowledge concerning the motor is much less general and much less perfect than knowledge of the dynamo. The reason for this is probably that most persons fail to understand these slight differences in action and are therefore apt to assume either that the two machines are exactly alike or entirely different, neither of which assumptions is correct.

The key to the action of the motor and particularly to the difference between it and the dynamo is its counter electro-motive force. In the case of the dynamo there exists only one EMF, whereas in the motor there must always be two. The difference between the two cases may be expressed very simply in the following way:

One kilowatt dynamo,

$$C = \frac{E}{R}$$

$$10 \text{ ampères} = \frac{100 \text{ volts}}{10 \text{ ohms}}$$

One kilowatt motor,

$$C = \frac{E - e}{R^1}$$

$$10 \text{ ampères} = \frac{100 \text{ volts} - 90 \text{ volts}}{1 \text{ ohm}}$$

$C$ is the current;
$E$, the direct EMF;
$e$, the counter EMF;
$R$, the total resistance of the circuit;
$R^1$, the resistance of the armature.

The current and direct EMF are the same in the two cases, but the resistance is only one-tenth as much in the case of the motor, the difference being replaced by the counter EMF of 90 volts, which acts like resistance to reduce the current.

The counter EMF of a motor is the necessary result of the rotation of its armature, as may be shown by the fol-

lowing experiment. Let us take two identical machines, one of them being connected to the electric light circuit, the current from which causes the machine to run as a motor. This machine is belted to the other machine, which is thereby driven as a dynamo. Now in both cases we have identical armatures revolving at equal speed in magnetic fields of practically the same strength. It is obvious, therefore, that nearly the same EMF must be generated in each machine, because in both cases practically the same number of lines of force are cut by an equal number of turns of wire revolving at the same speed. In the case of the dynamo this EMF produces a current which may be used to feed a certain number of incandescent lamps. In the case of the motor the EMF is opposed or counter to the direct EMF of the electric light circuit, and the current produced is due to the difference between the two, as expressed in the second of the preceding equations.

It may be asked why this EMF is necessarily a counter one. The answer is that if we trace out the direction of the motion and of the lines of force, we shall find in every case that the EMF generated is opposed to that which produces the rotation of the armature. The real significance of the counter EMF is that it represents the amount of electrical energy that is taken out of the electrical circuit, so to speak, and converted into mechanical energy.

This is the way in which nature always works in converting electrical energy into any other form of energy, with the single exception of the production of heat by the passage of current through a resistance. This last, however, is not a true case of conversion, being a frittering away of energy similar to the production of heat by friction. In all other cases the counter EMF is always present. For example, when electrical energy is converted into chemical energy in the charging of a storage battery, or the decomposition of water, there is in every case a counter EMF. In the same way, when an electro-magnet is charged and electrical energy is converted into magnetic energy, there is a counter EMF which opposes the magnetizing current and is commonly known as the counter EMF of self induction. This counter EMF is indeed a most remarkable and interesting phenomenon, and throws considerable light upon the relation of the various forms of energy and the manner in which one is converted into another.

In the case of the motor, the counter EMF actually represents the amount of electrical energy converted into mechanical energy, and therefore determines the efficiency, and the so-called electrical efficiency, or conversion-factor, is equal to

$$\frac{\text{Counter EMF.}}{\text{Direct EMF}}$$

The actual or commercial efficiency is somewhat less than this, owing to friction, Foucault currents and hysteresis. The counter EMF also determines the speed and many other facts in the working of the machine.

In the minds of many persons the counter EMF is thought to be merely a "scientific idea" or a mathematical abstraction which has no real existence or importance. Nothing could be more erroneous than any such opinion. The counter EMF is just as real as the direct EMF. We have already seen that it must necessarily be produced whenever the armature revolves. It is somewhat difficult, however, to actually measure or show it. From its very nature it is covered up, so to speak, by the direct EMF. The ordinary way to determine it is to find the value of the direct EMF, the resistance and the resulting current; the counter EMF is then found by the following equation: $e = E - CR$. It is also possible to calculate it in the same way that the EMF of a dynamo is determined, if the number of turns of wire, speed of rotation and number of lines of force are known.

The following experiment actually shows the existence and value of the counter EMF. Let us take a plain shunt-wound motor, provided with a fly-wheel, and run it from a constant potential circuit of, say, 110 volts, and

while it is running at full speed, entirely disconnect it from the circuit. It will continue to run by the energy of the fly-wheel, and it will then act as a dynamo and generate an EMF of nearly 105 volts, which is tested by connecting a volt meter to the two brushes. This EMF is practically identical with the counter EMF which the machine was producing the moment before while running as a motor, provided, of course, the test is made immediately, so that the speed does not have time to fall appreciably. It should be remarked, also, that the strength of the field magnetism is slightly less, owing to the fact that it is fed by the EMF of 105 volts generated by the machine itself, instead of by the 110 volts of the circuit; but if the magnetism is nearly saturated this will only reduce the number of lines of force one or two per cent. Several incandescent lamps can be connected in parallel across the terminals of the machine and the energy in the revolving fly-wheel is sufficient to keep them glowing for one or more minutes. If a lamp is kept connected across the terminals of the motor while the switch controlling the circuit is alternately opened and closed, it is possible in this way to compare the direct and counter EMF by the variation in the brightness of the lamp, and it will be seen that the latter is only slightly less than the former.

A still more striking demonstration of the reality of the counter EMF may be given by running the motor with a certain amount of resistance in its shunt field circuit, so that the field magnetism will be below its normal value, in which case the speed will be higher than usual. If the machine is now disconnected from the circuit and the resistance is afterwards cut out of its field circuit, the EMF produced will become actually higher than the original direct EMF; in fact, it is possible to obtain two or three times the original voltage. We have here a new method of converting electrical energy to a higher potential, being a sort of direct-current transformer, which, however, is quite different in principle from the ordinary dynamotor. The important matter of governing the speed or power of electric motors depends largely upon the phenomenon of counter EMF. For example, the various methods of regulating street car motors, *i. e.*, the simple rheostat, the "loop" for short-circuiting one of the field coils, the "commutated fields" and the "series parallel controller," all act to adjust, or make up for, the variations in counter EMF which result from changes in speed. The most awkward matter in working electric motors is to control the current when the counter EMF is very low, due to the fact that the motor is starting or running slowly, and up to the present time there is no very satisfactory solution of this problem. The introduction of resistance in series with the armature is usually the simplest and most successful plan, but this is very wasteful of energy and involves the use of a large and clumsy rheostat.

The paradoxical fact that the speed of the ordinary shunt-wound motor increases if its field magnetism be weakened is also due to the counter EMF. This is easily understood if we remember that the counter EMF is reduced by weakening the field magnetism; consequently the current is increased in strength, and the speed rises until the counter EMF reaches a sufficient value to shut off the excess of current.

The writer showed, several years ago, that a motor can, in a very simple manner, be designed to run at a constant speed, or even at a higher speed, when fully loaded than when lightly loaded. This may be done by slightly exaggerating the effect of armature reaction so that the field magnetism will be considerably reduced by the large armature current which flows at full load, thus diminishing the counter EMF and increasing the speed in the manner just explained. In this way the remarkable effect of greater speed with heavier load is obtained without any special device or construction. These examples demonstrate the great significance and importance of the phenomenon of counter EMF in the action of the electric motor.

# MODERN BOILER MAKING.

*By William O. Webber.*

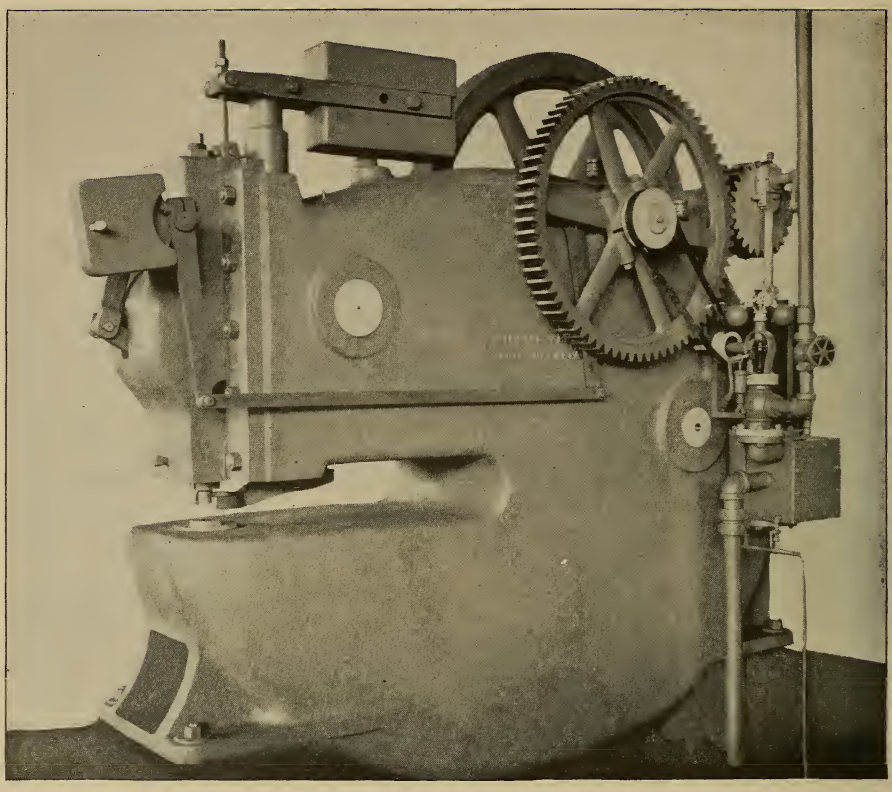
WITHIN the past decade the use of open-hearth steel has almost entirely superseded all other materials for boiler making purposes, owing to its extreme toughness and ductility, and the combination of maximum tensile strength with these qualities. When steel was first used for this purpose, high tensile strength was considered to be of prime importance, but it was soon found that toughness and ductility were of more essential value.

The first boiler steel specifications called for metal having a tensile strength of 60,000 pounds per square inch without much being demanded in the way of percentage of elongation, although hot and cold bending tests were specified. It was found, in practice, that these sheets cracked easily, especially when subjected to the sudden coolings due to blowing off and washing out hot—as was, of necessity, done with many locomotive boilers, particularly in cases where the waters used were very muddy and carried much lime and other impurities in mechanical suspension. For a while, therefore, steel was generally discredited for boiler making. Later on, it was found that a steel possessing from 50,000 to 55,000 pounds tensile strength, and an elongation not below 25 per cent. in 4 inches, and sufficiently low in carbon and other hardening constituents to allow of being heated to a dull cherry-red and plunged into cold water (60° F.) without hardening so far that a piece of ½-inch metal would bend double without showing signs of cracking, was a much more desirable material in every way for firebox and other stayed sheets, more especially those subjected to the direct action of the fire. A sheet as low as from 45,000 to 50,000 pounds tensile strength and an elongation of from 25 to 30 per cent. in 8 inches gave the best results.

About the first manipulation that the plates go through in the process of making a boiler, is the "laying out" as it is called. In works where standard sizes and styles of boilers are manufactured for the trade, templets are largely used for this purpose. Their outside contour is an exact copy of the shape to which the sheet is to be trimmed or sheared, and the latter has all the rivet holes along the edges and ends properly located, so as to match when the sheet is rolled into shape and joined to the other sheets, and on which, too, the holes for fire doors, manholes, hand-hole plates, domes and nozzles are all located in their proper places. These templets are laid on the sheets to be used and are marked through with white paint or other suitable material, and the sheets so "laid out" are passed on to the proper tools to be cut, punched or drilled as may be required.

In many of the larger shops a spacing table punch is used for punching the

WILLIAM O. WEBBER has had a varied engineering experience in a number of important positions, among them that of superintendent of a prominent engine and boiler works in the United States. He is a member of the American Society of Mechanical Engineers, and of the U. S. Naval Institute, and is now connected with one of the large pumping engine companies.



A PUNCHING MACHINE.

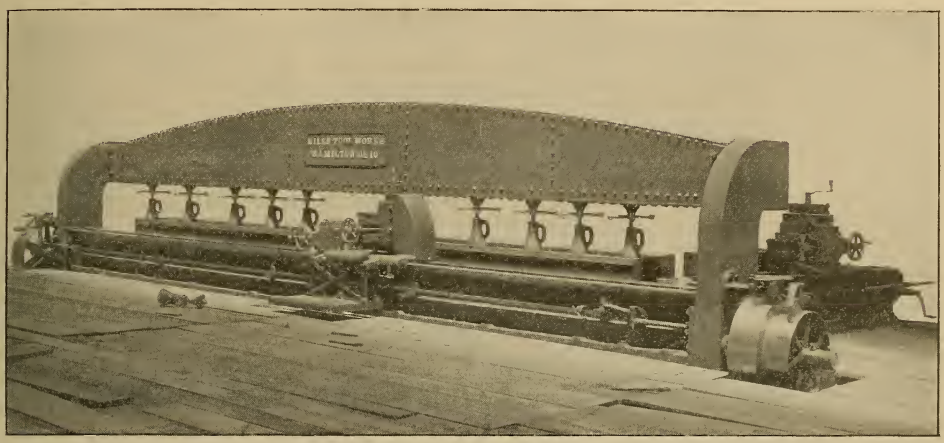
rivet holes along the edges of the plates. These tables are on wheels, geared to a traversing mechanism which moves them along the right "pitch" or distance to properly space the rivet holes a definite distance apart, so as to match the adjoining sheet or the opposite edge of the same sheet when the boiler shell is to be made of one piece, as is now quite frequently the case. Since the advent of plate mills capable of rolling plates of the largest sizes, some measuring 120 inches by 720 inches have been rolled successfully.

The heads are laid out in the same manner, generally after having been flanged, and the flue holes are now most generally punched out somewhat smaller than the finished sizes, and are then reamed out to the exact size required. Handholes and manholes are punched out in the ordinary way. Modern punches capable of punching 12-inch diameter holes in ¾ and ⅞-inch plates, and having a "throat" or "gap" of 60 inches, are found in the best equipped shops. Throat punches are used for punching rivet holes in close corners after the flanging is done, as the necessary flanging would distort the holes were they punched first.

After the plates are punched they go to the plate planer, where the edges are beveled to the proper angle to allow of being properly caulked after the boiler is shaped or riveted together. These plate planers are massive machines and have a capacity of taking in the largest plates, being so constructed as to allow of the longer plates being moved along and the edges subjected to adjacent beveling. Plate planers to plane 18 feet at one setting are not uncommon, and

the planing heads generally carry two tools, set in opposite directions, so that a cut is taken both forward and back and no time is lost in reversing as is common in most metal planers where with one setting, and are especially serviceable where sheets are to be planed to bevel or taper shapes for taper courses.

Under the general term of flanging



LATE DESIGNS OF PLATE PLANING MACHINES.

the work is moved along and the tool is stationary.

The tool-carrying saddle is moved back and forth by a large screw extending the whole length of the planer. A heavy clamping bar, which holds the plates in position, is raised and lowered by means of screws at each end. Other machines of this general type are arranged so as to plane two adjoining edges of a sheet at the same time, and

are embraced many of the most skilled and difficult operations of the boiler maker's art. A good flanger is as skilled a workman as, and needs the manual dexterity and judgment of, the highest class blacksmith. He must work much quicker, ordinarily—as the plates, being relatively thinner, cool quickly, and consequent reheating is costly as to time and destructive as to the material of the sheets. All regular

circles are mostly done on flanging machines, on which the sheet is clamped and revolved rapidly while red hot, roll-

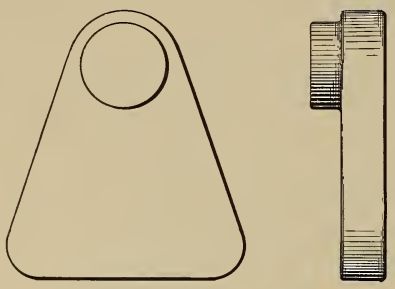


FIG. 1.

ers being pressed against the revolving edges to form the metal into the required shape. A few of the largest

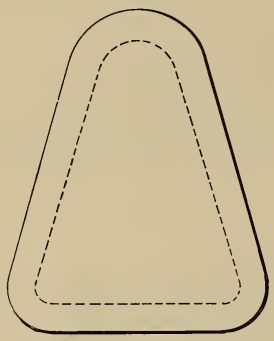


FIG. 2.

shops, producing a great quantity of duplicate work, are equipped with flanging presses, either steam or hydraulic, having dies and formers of the required shapes, between which the heated plates are laid and pressed at one operation into the required shape; or, sometimes, they go through one or more successive operations to produce the shape required. The making of these dies and formers requires great skill, based on practical knowledge, so that the shapes required may be turned out without unduly stretching or "drawing down" and "thinning" the metal at the corners, and are generally the result of successive experiments.

An example of this work may be of interest in which a sheet is to be flanged into the shape shown in Fig. 1. The sheet is first cut into shape shown in Fig. 2, the dotted lines outlining the shape and size of the turned over edge shown in side view in Fig. 1. A die of cast iron of the shape shown in Fig. 3 is then made. On this the sheet is laid and a former, of the size and shape of the inside of the sheet, is then pressed down on it, forcing it, in turn, down through the die and into the shape shown in Fig. 1, minus the circular projection on the left side near the top. A small hole is then punched in the cold sheet, in the centre of which the circular projection is to come, and the sheet is reheated around this hole to just include sufficient area to cover the outside shape

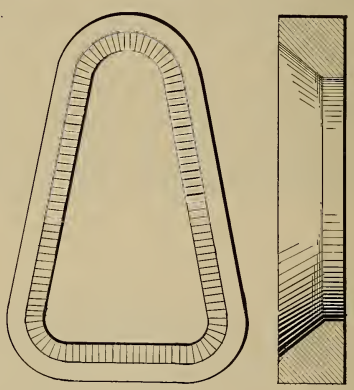


FIG. 3.

of this projection. The sheet is now placed in another die, large enough to hold the whole sheet from moving, and

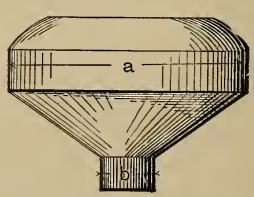
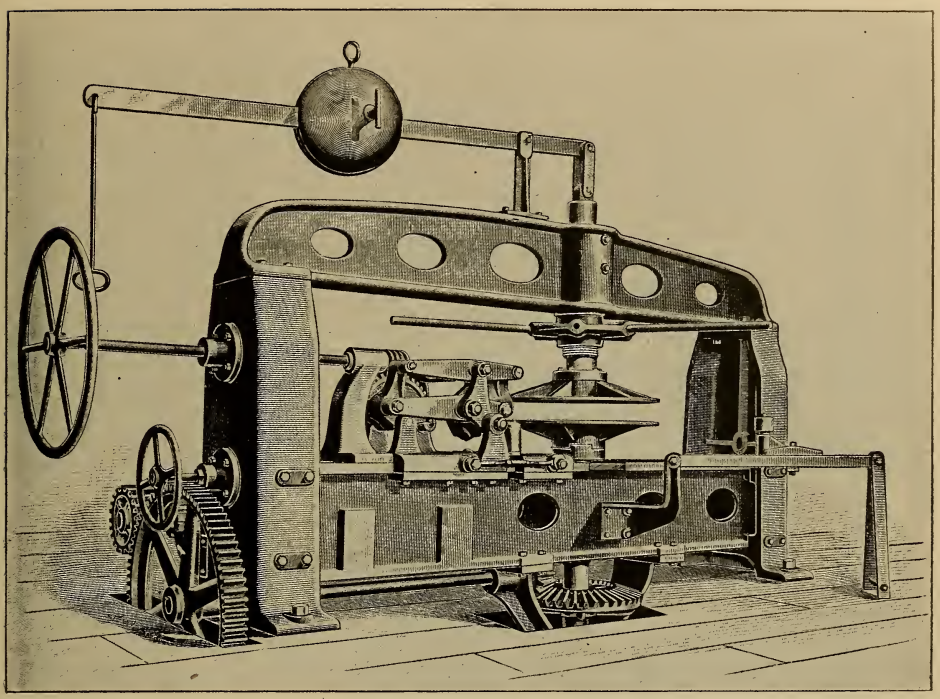
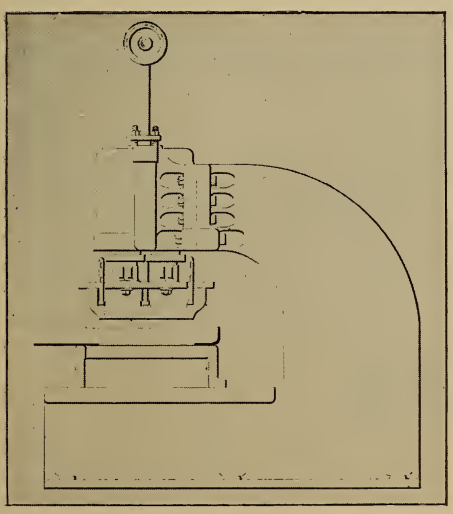



FIG. 4.

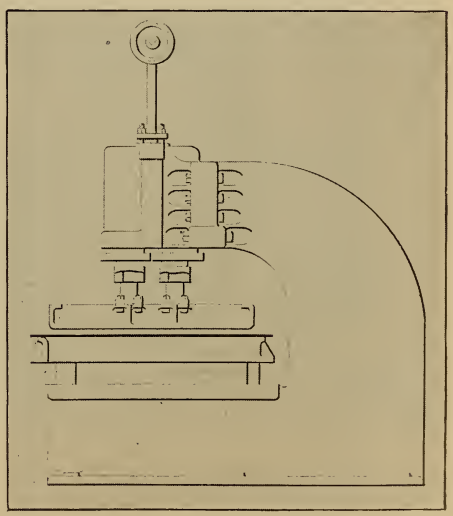
to properly locate the hole in relation to the outside of the sheet. It has a hole in it, of the style of the inside of Fig. 3,



A FLANGING MACHINE.

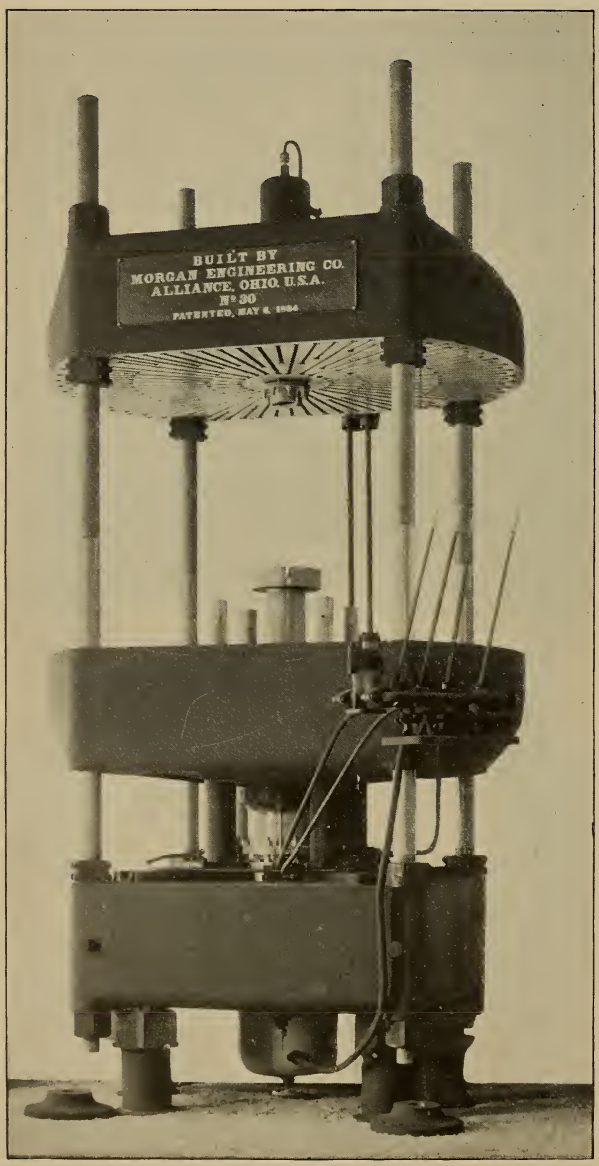


INTERNAL FLANGING OF FLUE HOLES ON AN HYDRAULIC PRESS.



FLANGING BOILER HEADS AT ONE STROKE.

but circular in shape and of the size at the bottom that the circular projection is to be. A circular die, shaped like

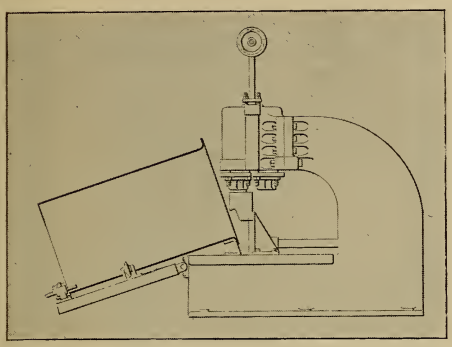



A HEAVY HYDRAULIC FLANGING PRESS.

Fig. 4, is then forced through it, the diameter at *b* being just small enough to pass through the hole punched in the sheet and the diameter at *a* being that of the inside of the flanged projection. The sheets being properly "laid out," punched and beveled, are now ready to be bent into shape to form the shell of the boiler. This is best done by a set of bending rolls, consisting of three rollers, two being located at the bottom in the same horizontal plane, and the other one, above and midway between the other two. The two lower rolls are fixed as regards their distance from each other, but are free to revolve on their own axes. The upper roll is carried in bearings mounted on heavy screws so as to allow of its being adjusted up and down. The closer down between the two lower rolls it is forced, the smaller the diameter of the rolled sheet will be. The rolls are made very heavy and strong, and are driven by powerful reversing engines direct-connected. In the larger-sized rolls for ordinary "land" boilers, capable of rolling up a sheet 20 feet in length, the lower rolls are 22 inches in diameter and the upper, or adjustable, roll is about 18 inches in diameter. The engines can be reversed with a single lever and made to roll the sheet backwards and forwards between the rolls until the required curvature is obtained. Heavier rolls are made for marine work.

The "shell," as it is now called, having been rolled into shape, the plates are joined together and fastened temporarily by bolts to hold them in relative position while they are being riveted. This is now done by powerful riveting machines, worked either by steam or hydraulic power. These ma-

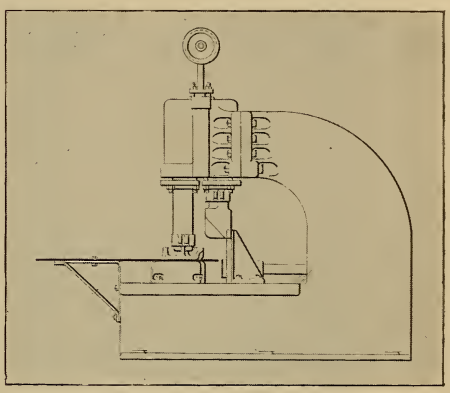
chines have gradually grown in size until those having a "gap" of 16 feet are not uncommon, and some of even greater gap have been recently constructed. These machines consist of a horizontal



FLANGING FLUES.

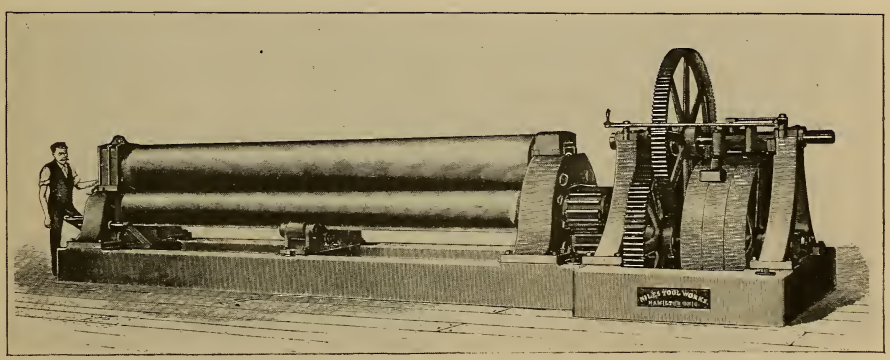
cylinder located on top of a very heavy casting or frame, and carrying a piston, whose rod is attached to a cross-head moving between heavy slides or guides, and carrying, again, on its front end, a "die." The end of this is "cupped," corresponding to the shape of the finished rivet head. In front of this heavy rame is bolted a "stake," generally of

just mentioned, but being cupped like the frustrum of a cone instead of a full cone. These two dies are in exact juxtaposition, and must be so, in order to do good work.



SECTIONAL FLANGING.

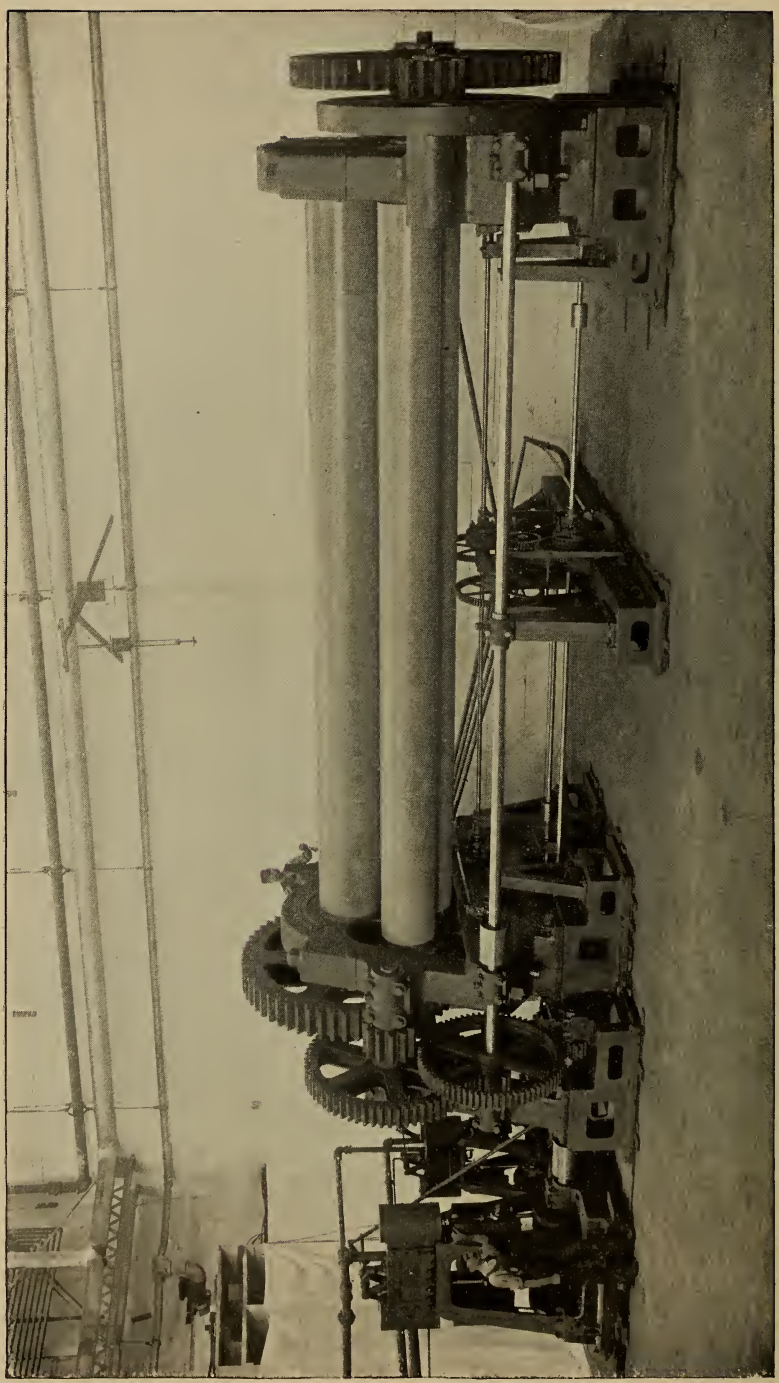
The "stake" is bolted to the main riveter with very heavy bolts just below the floor, and its lower end extends below the floor nearly as much as its upper end projects above. The boiler is lifted up by heavy traveling cranes and is dropped down over the stake, so



A SET OF POWER BENDING ROLLS.

cast or forged steel, and of massive proportions below the floor line, tapering up as small as is consistent with requisite strength above the floor, and carrying on its inner face a die corresponding to the one on the cross-head

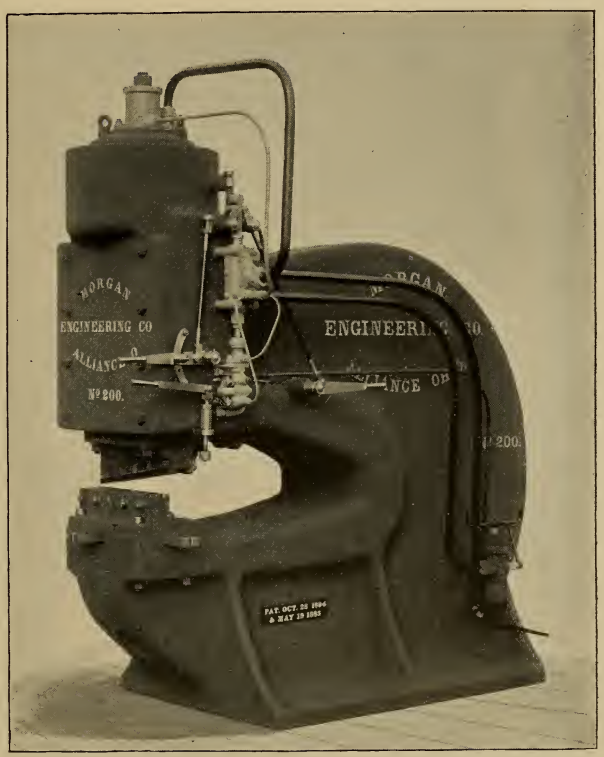
that, a red-hot rivet being placed in a hole in the shell, the head of the rivet comes in the die in the stake. Steam or water under pressure being admitted behind the piston, the die on the cross-head is forced up against



A SET OF BENDING ROLLS WITH INDEPENDENT ENGINE.

the projecting end of the rivet, forcing the body of the rivet out until it entirely fills the holes in the two edges of the sheets lapped together, upsetting the end into another head, and firmly forcing the two sheets together and holding them there under pressure until the rivet is "set" and the sheets are properly united.

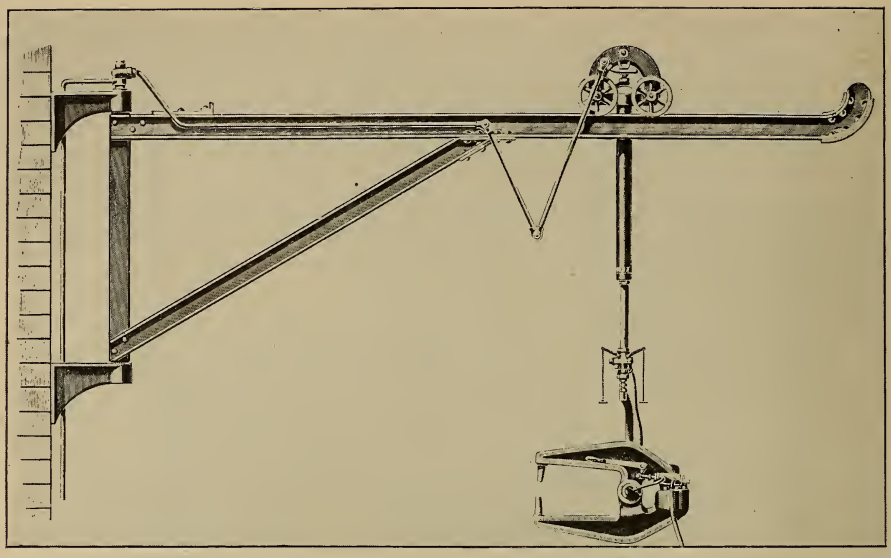
Some idea of the pressure brought heavier pressure to squeeze the sheets together and form the rivet heads. Another recent improvement in these machines consists in cutting away the top guides which carry the cross-head, moving the cylinder further back and placing the die as near the top surface of the cross-head as possible. This allows of rivets being driven in very close proximity to a projecting piece




AN HYDRAULIC PLATE SHEARING MACHINE.

to bear on a ¾-inch or ⅞-inch rivet by this kind of a machine may be realized when it is understood that a 36-inch steam piston is used, having an area of about 1017 square inches, on which a pressure of 125 lbs. to the inch is applied, making a total pressure of 127,225 lbs., or about 63 tons. The steam riveters are now constructed with a peculiar valve which admits only part of this pressure at first for upsetting the body of the rivet, and then lets on the or flange, like the dome of a boiler, or where the "throat" sheet joins the "waist" of a boiler.

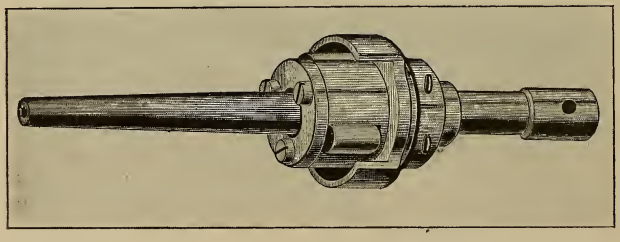
Of course, there are a great many instances in which work cannot be reached by the power riveter, such as in riveting in the braces, setting in the second boiler head, where both must have their flanges turned towards the centre of the boiler, and other cramped work difficult to reach. This must all be riveted by hand or portable riveters,



A PORTABLE RIVETER AND CRANE.

three men usually being necessary in hand riveting, besides the boy to heat and pass the rivets. One man, the helper, is provided with a long iron bar having a head like a wooden mallet, the faces being cupped to receive the head of the rivet. On this bar, located some little distance back from the head, are two or three holes, six inches or more apart, by which this bar is suspended from some part of the boiler. The helper puts his weight upon the long end of the bar and holds the head up against the head of the rivet, while the two "riveters" strike the other end of the rivet alternately with two small hand hammers, upsetting this end and forming the rivet head, which may be finished by using a die having a wooden handle like a hammer. This die is held on the rivet and struck with a slegde in the same way that a blacksmith's "flatter" is used. By this method all nozzles, brackets, loops, etc., are riveted to the shell of the boiler.

Next in order comes the "flue setting." The flues are lengths of the very best charcoal-iron pipe, and are inserted in the heads of the boilers, extending from one head to the other. The "layout" of the flues, as it is called, that is, the number, arrangement and size of the flues, is as variable as the moods of man. Some engineers want as many flues of small size, as closely spaced, as possible; others go

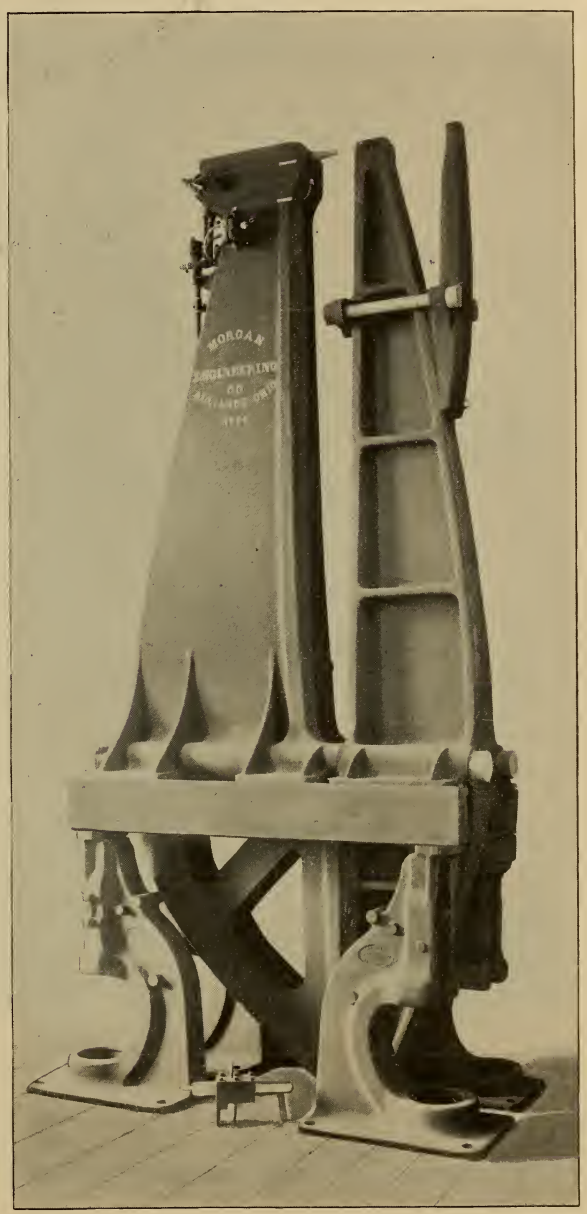


A TUBE EXPANDER.

to the other extreme and want only two flues of the largest diameter possible. These very large flues are riveted in. The usual sizes, however, are from 2 inches to 6 inches, and the preferable arrangement now is in vertical rows, spaced about ¾ inch apart from outside to outside, and with a somewhat wider space in the vertical centre of the boiler. Twenty years ago the favorite spacing or layout was on a hexagon, or as the cells are arranged in a comb of honey.

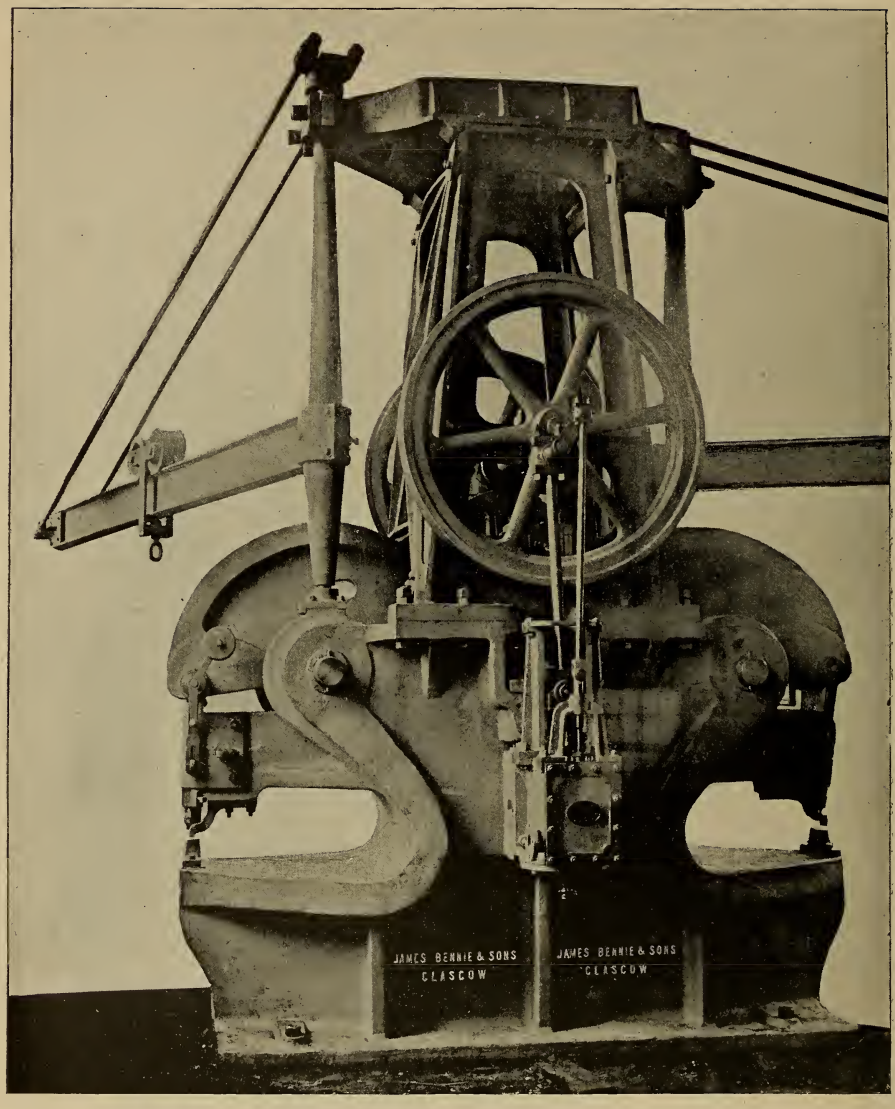
The flues having been inserted in the two heads, and being sufficiently long to project about $\frac{3}{16}$ inch from the outer face of each head, are fixed in position by a flue expander, as it is called. A common type of this tool consists of a set of three small grooved rollers of hardened steel, placed at intervals apart in a shell or case, just small enough to pass inside of the tube or flue. Inserted between the inner peripheries of these rollers is a long, tapering, round pin, or shank, of tool steel, the outer end of which is provided with a squared or hexagonal head, through which pass one or more transverse holes, at right angles, or 120° from each other. In these may be inserted a small iron bar.

The expander being now inserted in the flue so that the groove in the little rollers comes directly opposite the edges of the flue sheet or head of the boiler, the shank is driven in with a light hammer, forcing these rollers out against the inside surface of the flue, in turn forcing the flue out against the flue sheet. The slightly larger parts of the rollers on either side of the central groove cause the flue to bulge out, both inside and outside of the flue sheet.



A 17-FT. 2 IN GAP HYDRAULIC RIVETER WITH AUXILIARY STAKE. THE DEEPEST GAP STATIONARY RIVETER IN THE WORLD.

The central shank is now caused to revolve on its axis by the hand lever




A DOUBLE PUNCHING MACHINE WITH INDEPENDENT CRANES AND ENGINE.

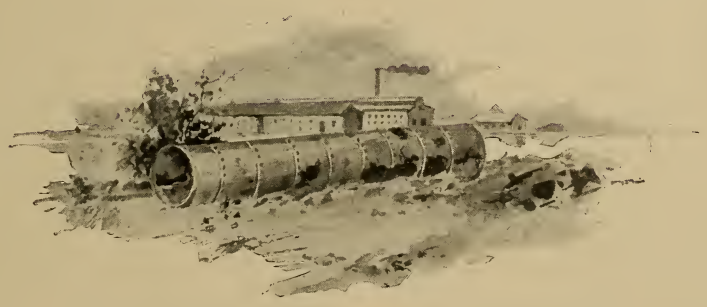
being inserted in the holes in its head and turned by hand, causing these small rollers to pass around on the inside of the flue, carrying the whole tool with them. This is repeated, the shank being driven in from time to time until the flue is sufficiently expanded to be steam and water tight under the pressure required. Some engineers prefer to have the projecting edges of the flues beaded in addition to the expanding, but this is not really necessary, although it makes a more finished-looking piece of work.

Then the boiler has to be caulked. This consists in applying a blunted chisel to the edges of each sheet where they overlap, striking it with a hammer, and upsetting the edge of the sheet so as to make it bear more firmly against

the adjacent one. A number of different shapes of chisels are used, but the most popular seems to be one having a rounded head, making a corresponding groove in the edge of the sheet and forcing, as it were, a wedge of the metal of which the sheet is composed between the two rivet heads. A number of power caulking tools have been invented; one, driven by compressed air and operating very much like the "plugger" with which we are all quite painfully familiar in our dentist's hand, is in quite general use.

Finally, the boiler goes to the testing room, where it is first subjected to an hydraulic pressure of from two to three hundred pounds per square inch. The water pressure applied is generally double that of the steam pressure to be carried. The leaks, if any, are caulked tight under this pressure, and any unsound rivets are marked to be replaced. Then the water is drawn off and steam is used in its place, and the boiler is made tight again under these new conditions.

The boiler is now drained of steam and water, given two coats of "black asphaltum" varnish, and is ready to go to its destination, being supplied with cast-iron front, stack plate, grates, grate-bearers, rear arch bars, rear ash door and frame, safety valve, steam gauge, water gauge fitted with standpipe, three gauge cocks, whistle and pipe, blow-off valve, check valve, stop valve, smoke stack, and wire-rope guys, generally about four times the length of the stack. Anchor bolts, buck stays, wall plate and rollers, and a set of fire tools, including poker, hoe and slice-bar, are usually extras which are furnished at a nominal charge.



# AN AUDIENCE WITH CARNOT.

## The Late President Carnot's Personality and Private Life.

*By Dr. Robert H. Thurston.*

"Dedicated to Sadi Carnot, president of the French Republic, that distinguished member of the profession of engineering, whose whole life has been an honor to his profession and to his country, and who elevated to the highest office within the gift of the French nation, has proven by the quiet dignity and the efficiency with which he has performed his august duties that he is a worthy member of a noble family, already rendered famous by an earlier Sadi Carnot now immortal in the annals of science, and is himself deserving of enrolment in a list of great men which includes that other distinguished engineer, George Washington."

A NOTE enclosing a slip of paper on which was inscribed the above procured for the writer one of the most interesting and pleasant meetings with the distinguished martyr to the rising forces of anarchism that, among many occurring in the Exhibition Year, 1889, it was his good fortune to enjoy.

Suddenly and unexpectedly called, "by cable," to take part in the work of the International Jury of that year, work in hand was dropped at a day's notice. A telegram to Cook's office, "How soon can you put me in Paris and by what route?" received answer almost within the hour, "City of Rome, to-morrow morning, Paris June 6," and that night the traveler was on the train for New York, and next afternoon he was over the bar, steaming rapidly toward Liverpool on one of the most comfortable ships ever built.

Reaching port at the same time with the delegation of members of the great societies of American engineers, visiting their British cousins and by them received with such unexampled hospitality, a break in the journey was made in order to take part with them in their excursions to Crewe, Manchester and London, and to arrange a return for the formal reception and the great "Guildhall Banquet"; but Paris was reached in time to take part in the opening session of the International Jury in the Trocadero and for assignment as vice-president to "Class" and "Group Juries."

Kind and influential friends in Paris, intimate with the family of the president of the French Republic, and especially official connections with the administration of the Exposition, gave many opportunities, in the course of the season, to see, and to learn through his friends, much of the life and work and thought of the quiet, dignified, and always courteous and kindly Chief Magistrate. Receptions at the Palais de l'Elysée, frequently occurring throughout the summer, visits with representatives of the scientific and engineering societies, and invitations by the president and members of the cabinet to the opera and to their various man-

Dr. Robert H. Thurston will always be honored and esteemed by all who are interested in mechanical engineering as one whose entire life has been devoted almost solely to the advancement of that noble profession. After active service in the United States Navy during the great Civil War, as assistant engineer he held a professorship at the United States Naval Academy for several years. Having resigned in 1871, he became professor of mechanical engineering at Stevens Institute of Technology, where he remained until 1885. In that year he assumed charge of Sibley College at Cornell University, which has grown phenomenally under his direction. He was the first president of the American Society of Mechanical Engineers, and has been for many years a member of the American, French, Scotch, Austrian and German Societies of Civil Engineers, the American Institute of Mining Engineers, the British Institution of Naval Architects, and the British and American Associations for the Advancement of Science.

sions, too, gave frequent and welcome opportunity to see more of the distinguished son of a distinguished family. The Carnots have been well known as able men, and as powerful elements in the direction of the life of the French people, for generations, and the Carnot of the time of Bonaparte, the "organizer of victory," the great statesman and engineer, was but a specimen of this succession of famous men.

A Carnot whose name is even more famous and more universally known than that of the great military engineer, the eulogist of Vauban and the Carnot of the Revolution, was a son of the latter, the first Sadi Carnot, "The Founder of the Modern Science of Thermodynamics." Like all these great men of the Carnot family, his genius was constructive and scientific. He distinguished himself as a student at the École Polytechnique, and, graduating at eighteen, did good service in the field until transferred to the staff and thus given leisure and opportunity for study.

The boy's genius at once flashed out as has that of few scientific minds in all history. At the age of twenty-four, he began a study of the principles of transformation of energy which resulted, in the year 1824, in the publication of that wonderful little book, "Réflexions sur la puissance motrice du feu,"—a work in which many of the grandest generalizations of modern thermodynamics were anticipated and which is to-day the corner-stone of the whole edifice of our theory of thermo-mechanical transformation and of the heat-engines. But the fame which came of this extraordinary display of talent was posthumous; the book attracting little attention until, years after the early death of its writer, Lord Kelvin, better known in science as Sir William Thomson, discovered it to the world. This Carnot was the grand-uncle of the late president of the French Republic. The Carnot of Napoleon's cabinet was the grandfather of the successor of Bonaparte of our day.

At the time of the hurried exodus of the writer, as above described, there lay on his desk, as it happened, a long-delayed translation of the "Réflexions" of the grand-uncle of our Carnot,—of the soldier, scientist, engineer, genius,—the publication of which had to be delayed until after the close of the Exposition. President Carnot was also soldier, scientific man, engineer, and a genius of another sort, but none the less thoroughly appreciative both of the work of his grand-uncle and of every testimonial to the worth and honor of his family and its great representatives. The dedication to the second Sadi Carnot, the president of the French Republic, of this first translation into English of the epoch-making tract seemed thus most appropriate. Hence the note to which reference has been made, and its enclosure,—the dedicatory inscription. Thus came about the meeting with this dintinguished, but never fully appreciated, Carnot.

Marie Francois Sadi Carnot was a son of Adolphe Carnot, in turn a son of L. N. M. Carnot, the statesman of the Napoleonic period. He was born at Limoges in 1837, and graduated with honors at both the Polytechnique and the École des Ponts et Chaussées, proving himself a good student, a genius in science and engineering, and an apt scholar in the art of war. He did excellent service, later, in the most difficult work of the military engineering division of the mountainous sections of the southeast of France. He saw active service at the siege of Paris in 1871, when he was made Préfêt de la Seine Inférieure. He proved a good soldier in the camp, a brave man in the field, and an admirable Commissary-General.

In politics, he was a republican, and was, later, elected by the Côte d'Or to the General Assembly. He was made Secretary of the Chamber of Deputies in 1876, sitting as member for Beaune. Still later, he was made Secretary of Public Works, and in 1881, Minister of Public Works; which position was surrendered to take, first, that of Minister of Finance, and then that of Premier, from which last lofty position he stepped, in 1887, into the

chair of the President of the French nation. His term would have expired last December, except for the crime of the assassin. His seven years of service as President came at a time when probably no other living man could have so successfully met the trials and difficulties of the position, or could have done so much to reconcile conflicting parties, to quiet the discontented, to give the people rest and calm, to promote the sentiment of patriotism and nationality, and that universality of industry, frugality and thrift, which so peculiarly distinguishes the people of France. None could so disarm the foreign, hereditary, foe of dislike and suspicion, engendered by centuries of strife.

The characteristics of this Carnot were industry, energy, conscientious attention to duty and to every detail of his work ; thorough knowledge of all the duties of the soldier, the legislator, and the executive officer of the nation ; the genius of his grandfather for statecraft, that of his father and grand uncle for both science and engineering ; that of the family for honorable diplomacy and leadership in an aristocratic, though republican, society,—the Royalists taking little part in the society of the republican court,—and a talent wholly his own for reconciling and combining innumerable contradictory elements in the complex structure of French life. His friends loved him ; his political enemies—he had no other—respected and admired him, and the world honored him for his lovable private life, his steady patriotism, his unfaltering courage, his fair and kindly treatment of citizens of all nationalities, his frank and honest diplomacy, and his unexampled powers of control of men, parties, the nation itself.

His reception of the royalty of Europe, of the Shah of Persia, of the representative of an arrondissement, of a wealthy bourgeois, of a poor ouvrier, or of whoever might come to him, was always quiet, dignified, appropriate and considerate. No ceremonial was forgotten or neglected in doing honor to a sovereign ; none was permitted to stand between the President and the humblest citizen. He was everywhere the President of France, always a self-respecting citizen, invariably a gentleman, representing to all the ideal man.

Carnot, in his home, according to the unanimous testimony of his relatives and personal friends, was as admirable as husband, father and host, as he was distinguished in his official relations. Kind and thoughtful, teaching all the domestic virtues by example, loving and lovable, charitable and hospitable, his was a home in the best sense, and to it all his friends were heartily welcomed, and in it made to feel that their presence was a pleasure to host and hostess.

In the creation of a social circle and of a cultivated court society, he was most efficiently assisted by Madame Carnot. Herself brought up under the most fortunate of circumstances, educated, cultivated, familiar with all that constitutes good society, whether in the home circle or in the salon, herself talented and accomplished, good as to heart, brilliant as to mind, with a soul steeped in "sweetness and light," Madame Carnot made the inner life of her husband richer, and its best part better, by her lovely character and beautiful life, as well as by her power of adaptation to the singular conditions by which they found themselves environed. Her own family claimed and received her first attention ; her political and social duties were never neglected ; but it was in the plentitude of her charities that the mass of the French people recognized her manifold virtues most fully.

That strength, courage, hopefulness, should suffice for such unending and tremendous labors as were demanded of the President in his public and private capacities is a matter of wonder ; but that his wife should carry such burdens as were unavoidably cast upon her delicate frame is even more marvellous. She had not the appearance of a woman of exceptional strength ; but there was a quiet, steady, pleasantly composed expression of countenance, observed by all who met her, which gave indication that her mind saved her muscles and nerves all unnecessary waste of power,

and thus enabled her to apply usefully and effectively every latent energy. It was of some such pair as this that Tennyson must have thought as "yoked in all exercise of noble end," and of such a woman as

"At the last, she set herself to Man,
Like perfect music unto noble words."

An audience with Carnot, under the circumstances, attracted one as a peculiar privilege and the tragic fate of the man lends to the reminiscence an intensified interest. Frequent invitations to the Palais de l'Élysée, at which honor was paid to dignitaries of every grade, to the opera when, as was common, the Government gave entertainments, to various fêtes at which the people came in enormous crowds, had made the manner and method of reception by the President on formal occasions, thoroughly familiar. The reception of a little party of representatives of the great European and American societies of his own guild,—the engineers,—had given closer touch and intensified the pleasant impression made by the President previously; but only when alone with him, face to face, and eye to eye, could the man be read and interpreted.

The hour assigned was noon, on a pleasant day in August, at the audience-room of the President at the Palais de l'Élysée. The Secretary made the somewhat pathetic suggestion, "the President is not well; make the interview as little of a tax as possible," and was promised that five minutes should cover all requirements; but the President himself detained his visitor until other engagements of the latter, as well as conscience, pleaded for its termination.

At the stroke of the clock we were in the outer reception room, a clever young literary friend going along as aid, interpreter, should one prove necessary, and as bearer of a copy of a little treatise by the writer on the "History of the Growth of the Steam Engine," which contained some reference to the work of the first Sadi Carnot,—perhaps the first recognition by any technical writer, in English, of the indebtedness of the theory of the steam engine and of modern science to that great author, and which book had been translated, some years earlier, by Professor Hirsch, a mutual friend of its author and the Carnots. It was thought that it might prove a welcome and acceptable introduction to our business, and had been, by a singular and happy accident, only the day before discovered in a handsome presentation binding,—the only copy, perhaps, in Paris at the time in that form—in one of those seductive shops, filled with all literatures, which line the further bank of the Seine, opposite the Latin quarter. After waiting a short time, while a delegation of representatives of the South of France, at the moment paying their respects to their chief magistrate, were taking leave, the Secretary appeared and led us into his presence.

As the door opened, President Carnot rose from his desk and came forward, with extended hand, with dignity, cordiality and courtesy marking every movement and expression. He impressed one as a tall, dark, slender, graceful man, with black hair, eyes and beard. The complexion was a trifle pallid, from a headache, as he explained presently, though usually showing some color. The clear skin, the bright look, the steady hand indicated the active nervous temperament which so frequently characterizes such men, and which the quick, precise motions of body and limbs continually illustrated as he led his guest to a seat and took the lead in the conversation, occasionally stopping for a moment to consult with the always busy Secretary who now and then came in to ask for instructions. Hair and beard were closely trimmed, and a heavy moustache partly concealed a mouth which could, however, be sufficiently well seen to show that firmness was not extinguished by good temper and habitual courtesy, nor kindliness by experience with the sad and the bad aspects of the world about him. Play of expression on the mobile features never ceased when in conversation, and lent attractiveness to a countenance always pleas-

ing and satisfying. The face was not what we are accustomed to call handsome ; but it was what is better, refined and pleasing as a mirror of the play of thought within the man.

The first business of the meeting was soon disposed of satisfactorily to the visitor. The subject was introduced by a reference to the work of Sadi Carnot, the thermodynamist, and the president carefully marked the place in the "Histoire de la Machine à Vapeur," at which occurred the statement made by the writer, ten years earlier, of the indebtedness of the science of the heat-engines to that great pioneer.

*The little gift was accepted with well-chosen expressions of appreciation both of the thought of the giver and of the recognition which the earlier genius had been accorded as the "founder of the science of thermodynamics," and the proposed dedication of the translation of his Réflexions was acquiesced in, with a little of that natural hesitation which a modest man must always feel when threatened with being pilloried in that manner. He objected, however, to a formal permission, as possibly interpretable as indicating an initiatory on his part, while frankly admitting that it was a welcome compliment both to himself and to his family. He was especially pleased that his relative should find so much appreciation in the United States as to induce the first issue of an English translation of his work in that great Republic of North America.

The reference to Washington as an engineer made a marked impression upon him, and he was much pleased to find that a statesman whom he so greatly admired, and the first president of the United States, and thus, in a manner, related to himself, should have been, like himself, a member of that great guild which, from the days of Tubal Cain, and of Hero and Archimedes, and of Leonardo and Lord Worcester, had been the constructors of the material basis of every civilization. He was familiar with the life of Washington, from Braddock's field to the president's chair, and to his retirement and his "passing over" at Mount Vernon ; but Washington, the young surveyor, was a stranger to him.

It was no matter of surprise to find in him this professional pride and interest in all that related to its subject. It had been evident on many occasions. Himself familiar, as an expert, with the achievements of engineering, in some of which he had taken practical part, he never lost his interest in anything bearing upon either the work of the profession or the accomplishments of its members, always his recognized associates.

The working of the republican form of government naturally especially interested him. The advantage possessed by the people of the United States in being permitted to work out their own problems of political and social economy, without embarrassment by the proximity of suspicious or jealous neighbors, and unburdened by costly navies and tremendously heavy taxes for the support of the army, seemed to him the most fortunate aspect of their situation. He anticipated a great and glorious future for the French Republic, but felt that the prosperity of his people was constantly threatened with disaster by this strain which the European governments are putting upon each other with continually increasing intensity.

"What will be the end of it all?" was asked of Carnot. He hoped and believed that, ere long, in the desperate straits of threatened general bankruptcy, some statesman might rise whose patriotism and good sense and whose influence upon the governments of the three or four, perhaps four or five, most powerful countries might bring about a general disarmament, with treaties binding the alliance to discipline any nation attempting to raise an army or build up a navy in excess of the assumed requirements of a peace basis or of an established and definite limit. The arbitrament of an

* Histoire de la Machine à Vapeur, par R. H. Thurston ; revue, etc., per J. Hirsch ; Paris, Gevmer, Baillière & Cie., 1880; translated from "The History of the Growth of the Steam Engine;" N. Y., D. Appleton & Co. (International Scientific Series), 1878.

International Court must, in time, take the place of war in the settlement of international disputes; but it could probably come only when the principal nations were unable to find capital for investment in extension of their preparations for war.

Carnot was himself precisely the kind of man to bring about such a termination of the long agony of the overtaxed and overworked people of Europe; but, even had he lived, it is unlikely that he or any other citizen of the French Republic could have successfully overcome the enmities and jealousies which France has accumulated during the century. Germany is much more likely than any other continental power to inaugurate and carry to a conclusion this greatest of the tasks of modern European diplomacy; while Russia is likely to present the final obstacle.

Of all these nations, France is perhaps best prepared to carry the load meantime. The steady, self-sustained industry of her people, their thrift and freedom from pauperism resulting largely, no doubt, from the universal requirement of a dowry for every girl before marriage,—and their correct methods of agriculture, perhaps no less, give the nation wonderful earning and recuperative power. Its army of men in the barracks is supported by an army of women in the fields and in the shops, and the population makes the most and the best of the situation. Carnot felt little anxiety about France, provided actual war could be averted; and he did much in the six years of his presidency to make the tension between France and Germany less. Possibly the tragic circumstances of his death may have accomplished as much in this direction, as did the frank and honest diplomacy of his official life.

Like every great European statesman or official, Carnot was particularly interested in the problems of education as worked out in the United States, and his questions were such as indicated considerable previous acquaintance with American public school systems, and some knowledge of the higher education, especially of technical instruction in that country. He felt that France was doing an admirable work; yet, he recognized the fact that the education of the whole people up to the point of at least reading the daily paper, and of capability of keeping accurate book-accounts, and especially to such a point that they should be able to think out for themselves those political problems which, in the course of time, they must inevitably confront and solve, is the first and greatest duty of a republican government, and his active mind was evidently continually seeking still more effective ways of reaching that great end.

The fact, of which he was aware in a general way, that the United States expends, annually, nearly as much for the education of the people as all of Europe, and hardly one-tenth as much for armaments and war was another reminder of the galling burden of the war-tax levied upon his country by the proximity of hostile neighbors. England, France and Germany spend, annually, from $125,000,000 to $175,000,000 for war, and from $35,000,000 to $50,000,000 on education. The United States of North America expend about $75,000,000 for war and $135,000,000 for education, without counting the unknown amounts, of enormous aggregate value, contributed by private philanthropy. Carnot saw in these contrasts impressive arguments in favor of complete reversal of the European policies in respect to international relations.

When informed that the care of higher education, formerly entirely dependent upon charity, in the United States, was coming gradually to be assumed by the States, and that 150,000,000 acres of public lands have been donated to this cause, that three-fourths of the States have founded State universities, and that, in all, education in all studies relating to the industrial arts are carried on side by side with literary and scientific instruction, he was surprised, but evidently pleased, to find that an experiment which had, in Europe, been generally regarded as unpromising, if not absolutely impracticable, had there been successfully conducted.

The "Morrill Bill," the "Land Grant Act" of 1862, giving each State 30,000 acres of public lands for each unit of its representation in Congress, to be applied to the promotion of technical education, was to him a splendid illustration of real statecraft. He asked if the tax for the pension list, which he understood to be enormous, was not a serious burden. When assured that it was not felt to be so, so far as honestly applicable to men who had seen real service and actually suffered disability through such service, and that it seemed very possible that this immense sum, now about $150,000,000 annually, might, in time, be diverted to the promotion of education and public improvements, he said that American public policy in that respect was, as he thought, most wise and commendable. He believed unreservedly in the policy of the education of the people for the life and the work of the people at whatever cost, and in the provision of a higher education for those competent to avail themselves of it, and especially as providing teachers of the people's schools.

The pyramidal scheme of education, primary schools, secondary, and collegiate instruction, in due proportion, sustained by the State, constantly supervised by its officers and held up to a high standard and in due symmetry by them, seemed to him ideal, and this system, he thought, was already well illustrated in the French organization. Washington's plan of a National University, and his gift of his Potomac company's stock to promote that still unaccomplished project, struck the imaginative side of the President with great force, and he was evidently disappointed, when told that, although every president of the United States, since Washington, had approved the scheme, and committees of Congress had almost annually, and always urgently, recommended its inauguration, not a step had yet been taken toward the erection of this final and greatest element of the American educational system.

Every aspect of progress in education of what the American Land Grant Bill calls the "industrial classes" was of great interest to him, and it was a source of great satisfaction and pride that he found that France was recognized in America as the pioneer among nations in the organization of systems of industrial training and of technical education; that her Conservatoire and her Polytechnique, École Centrale, and École des Ponts et Chaussées were regarded as examplars for all the world.

President Carnot was intensely interested in the success of the Paris Exposition. It had been organized in the face of great discouragements. Germany would send nothing; the other European nations took less interest than usual, as was surmised because it was professedly intended to celebrate the foundation of the French Republic, and the United States had, as usual, contributed comparatively little. The Exposition was, on the whole, a French Exposition, and magnificently did France sustain it. The hearty appreciation by the American people of the splendid display of France at the Exposition was a source of great pleasure and comfort to Carnot and went far to compensate the coolness and sometimes even hostility of other nations. He could already see that the Exposition of 1889 was an accomplished success and a perfect triumpth, and his mind was at rest on that score.

Much apprehension existed lest the close, in November, should bring a disorderly and dangerous element into the streets of Paris, as soon as work could no longer be had on the Champ de Mars; but the President shared this apprehension, apparently, to a very slight extent, if at all. Events proved it to be without real foundation; the Exposition closed and all France was as peaceful as during its existence. It was, in all ways, a grand success, even from a financial standpoint, and its organization and administration brought out, in high relief, the efficiency of the European systems of business and the advantage of governmental control through its regular and wonderfully well-directed departments.

The conversation finally drifted to less important subjects. The exchange of a few words about the Carnot family and its living representatives, and the usual exchange of farewell courtesies followed, and the interview was concluded. President Carnot accompanied his guests to the door and turned them over to his waiting and anxious secretary, with a final handshake and pleasant adieu.

Our last recollection of Carnot brings up his pale, but bright and kindly, face, and the expression of friendliness and cordiality which accentuated his last words. This was the man whom all France loved, whom all the world admired and respected. This was the man who had done more for France than any sovereign who ever sat upon her throne, more for Europe than her statesmen are usually ready to admit, more for peace and good will upon earth than perhaps any human being of our, probably of any, time. But for his unusual tact and power, his ability, honesty, patriotism and exceptional personal and family influence, and his absolute freedom from even the taint of a suspicion, personally or politically, a revolution, rather than quiet and prosperity, European wars in place of universal peace, might have ruined the French people, impoverished Europe and reversed the course of its civilization for a generation. It was this man, the noblest character among the reigning monarchs of the day, that the assassin chose as his victim.

The proposed five minutes' interview was prolonged to a half-hour, though the President talked rapidly, seldom required explanation and seized upon an idea almost before it was formulated in words. His vivacity and quickness of apprehension and his clearness of thought and expression crowded much discussion into brief space, and the whole took much less time than is required to relate it.

The audience will always be remembered with melancholy pleasure as an only personal interview with a Carnot whose fame will deservedly grow larger and brighter, in time, as the magnitude of the service rendered France and the world by this genius of modesty and wisdom, by this good man and genuine statesman, becomes more fully recognized. In all history there are recorded the names of but very few men at once great, good and useful. Among them, among the first of them, will always stand that of Marie Francois Sadi Carnot.

# ELECTRICAL COOKING AND HEATING.

*By Nelson W. Perry, E. M.*

AN ELECTRIC FLATIRON.

WHEN, in the infancy of electrical science, it was observed that the passage of a current of electricity through a conductor was always accompanied by heat, and when the further study of the subject disclosed the fact that the amount of heat thus generated was an exact measure of the loss of energy occasioned by its friction on the wire, it was considered an unmitigated evil in the problem which had early been set of transmitting energy by electrical means from one point to another, and so it has remained to this day. But later discoveries have enabled the utilisation of this phenomenon in many ways by magnifying the effect at local points. By thus utilising a waste product, as it were, the world has been enriched by the essentially new arts of electric lighting, electric welding and forging and electric heating and cooking.

The ability to convert electrical energy into useful heat or to transmit it to distant points with but little such conversion at will, depends upon the principle that the heat generated by the passing current in a conductor is proportional to the square of the current and directly as the resistance. In simple language this means that if through a given conductor double or treble the current is passed, the heat generated will be four times or nine times as great, and that in two portions of a given conductor offering different resistances to the current, that one will get twice as hot which offers twice as much resistance.

For transmission purposes, therefore, the conductor is made large, so as to obstruct the current as little as possible, and at the point where heat or light is desired it is made small and of high resistance, so as to obstruct the flow of current to the requisite degree. In the distribution of current for the incandescent light, we have an illustration of this practice where a short length of very high resisting carbon is inserted in a copper circuit of low resistance. In this way the proper conditions are fulfilled, and we have a heat nearly sufficient to melt platinum, locally generated in the carbon filament, whereas the copper on both sides, through which the same current has passed, remains cool.

In electrical welding, we have a further illustration of electrical heating, the same in kind but differing in degree. Two bars of copper or other metal to be welded, an inch or more in diameter, are thus brought, at their

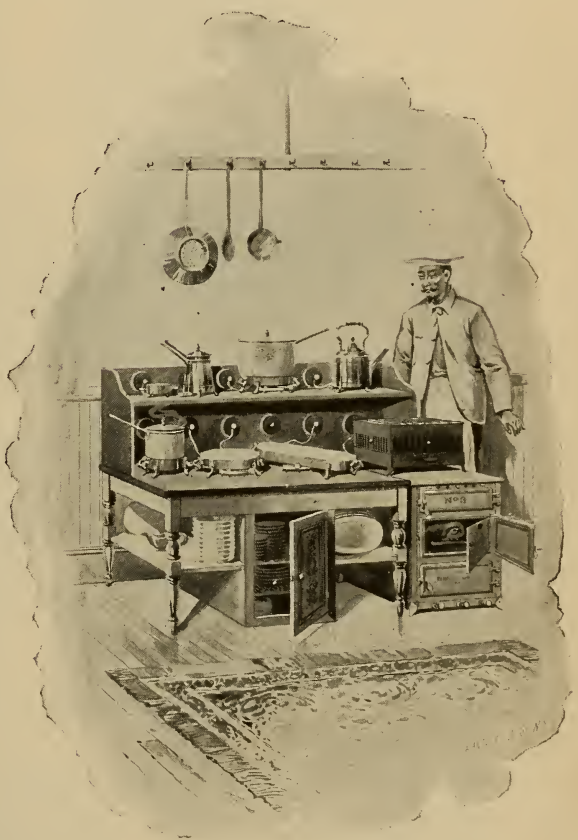
NELSON W. PERRY was graduated at Harvard University in 1876, and two years later received the degree of Engineer of Mines at Columbia College, New York, graduating as the first in his class in an advanced course in physics. For several years he was employed as economic geologist and mineralogist in the United States geological and geographical surveys, practicing also as mining engineer in the western part of the United States and in Mexico. Subsequently he occupied the chair of metallurgy at the University of Cincinnati. He has also been connected with several of the prominent electric companies, and, of late, has more particularly devoted himself to electrical pursuits. He is the recipient of the John Scott Legacy and Medal of the Franklin Institute of Philadelphia for his method of series electric traction, for many years has been a member of the American Institute of Mining Engineers and the Institute of Electrical Engineers, and has been elected to membership in the leading chemical societies of Berlin and Paris. Of electrical cooking and heating Mr. Perry can speak in a thoroughly authoritative manner.

juncture, to a welding heat in a very few minutes by the passage, from one to the other, of the requisite current. In this case both the bars are such excellent conductors that it would require a current of enormous proportions to heat them even sensibly to the touch ; but the point or points where the two bars touch each other when they are placed in position for welding, offers a comparatively enormous resistance, and consequently heat is almost immediately developed locally while the adjacent parts remain cool.

In applying the electric current to heating purposes, it is necessary, of course, to observe certain precautions, viz., not to make the resistance great enough to prevent the passage of the requisite current. Electricity is distributed to houses on the same plan as is water, namely, under a certain predetermined pressure. In the case of water this pressure is determined by the height of the reservoir whence the supply is drawn ; in the case of electricity it is the pressure which is given it by the dynamo in the central lighting station, and in both cases it is beyond the control of the consumer. He can reduce the pressure at his house if he choose, it is true, by introducing valves or resistances in his pipes or his wires, but he cannot, with the usual means at his command, increase that pressure at all. He must, therefore, adapt his devices in both cases so that they will operate within the pressures at hand. If an obstruction be placed in a water-pipe it will reduce the flow of water accordingly, and in the case of an electric current the flow will be likewise reduced by similar means.

As already stated, the heating effect is increased four-fold and nine-fold by simply doubling or trebling the current, but it is also true that the current flow will be reduced to one-half or one-third by doubling or trebling the resistance, and when such reduction of flow occurs the heat effects are likewise reduced, not to one-half or one-third, but to one-fourth or one-ninth. Thus, if too much resistance be used, the heat will be insufficient, and the desired results will be obtained only by a nice adjustment between the pressure and resistance.

If the filament of an incandescent lamp were made twice as long as it is, its resistance would be double and its temperature would be reduced to only one-fourth that required for brilliant illumination, and it would give but a dull red or no light at all under the

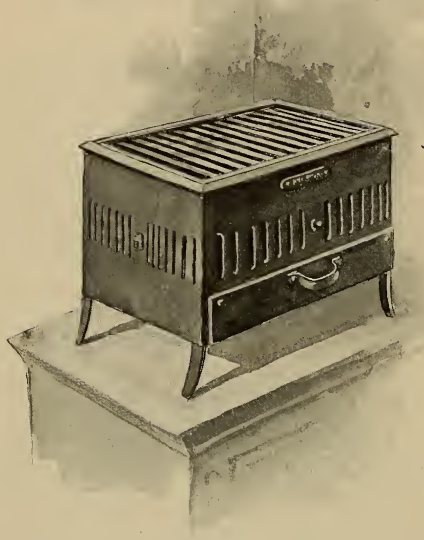


AN ELECTRIC COOKING OUTFIT.

usual pressure. If, however, we had another circuit with just double the pressure, this same lamp would burn on it with the same intensity as it did on the lower pressure circuit before its filament had been lengthened, because an increased resistance is exactly counteracted by an equal or proportionate increase in pressure.

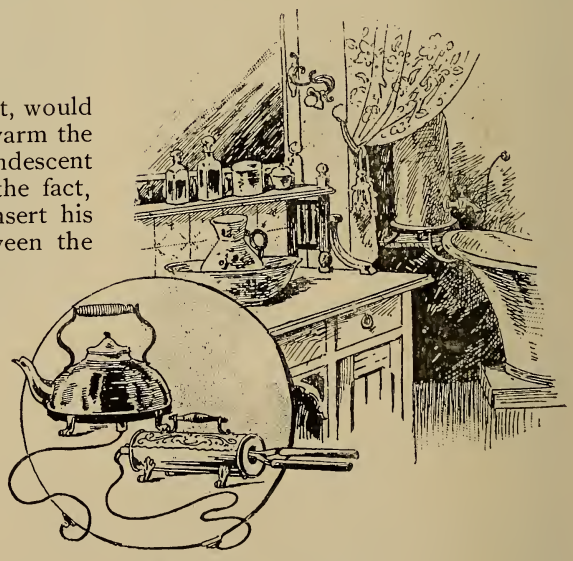
In electric welding, as a matter of convenience, extremely low pressures

are used—so low that the apparent startling anomaly is presented in the fact that the current which will, in a few moments, raise a bar of steel, two or three inches in diameter, to the



AN ELECTRIC BROILER.

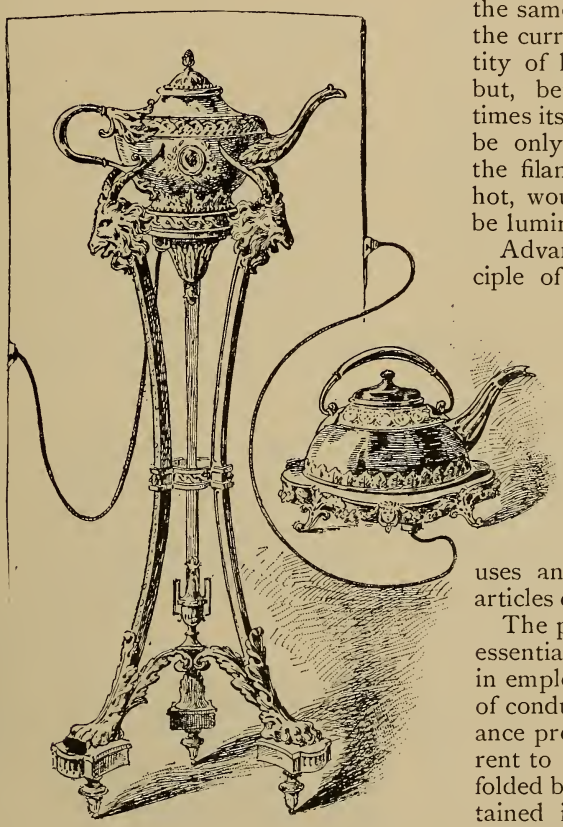
welding point, or to a white heat, would be totally insufficient to even warm the filament of an ordinary incandescent lamp. Still more startling is the fact, for it is a fact, that one may insert his hand, or even his tongue, between the ends of two bars of this size and, without ill effect, turn on full the current, which in the next minute would raise the metal rods to an intense heat upon bringing their two ends together. In both cases the explanation is that the resistances of the lamp filament and the hand or tongue are so great as to reduce the current that will pass under the existing pressure to a harmless degree. Another illustration of remarkable localized heating effects by electricity, which more recently created quite a sensation in the electrical world, is that of heating and even melting refractory metals, such as iron and steel, under water. This process, usually attributed to two Belgian scientists, Lagrange and Soho, may be described as follows: If to one side of an electric circuit there be attached a large plate of lead and to the other a small bar of iron, and if the two be dipped into a pail of acidulated water, so that the current passes from the lead plate through the water to the iron, then if the proper conditions be maintained, that part of the iron bar which is immersed in the water will at once be surrounded by an intensely luminous envelope and in a few minutes be entirely melted off, while that portion of the bar not immersed will remain so cool that one can handle it without discomfort to within an inch or two of the end that was melted away. The inventors claim that the temperatures attainable by this method vary from 4000 to 8000 degrees Centigrade, equivalent to 7232 and 14,432 degrees of the Fahrenheit scale. This is probably in excess



ELECTRICITY IN THE BOUDOIR.

of the fact, for it is not probable that the temperatures thus attainable greatly exceed those reached by the ordinary electric arcs which have hitherto marked the limits reached.

These examples well illustrate the extreme temperatures which may be attained locally, and it will be observed that they are occasioned in all cases by localizing the resistance, for in the last example the heat is supposed to be due to a very thin film of hydrogen gas surrounding the immersed iron, offering an extremely localized resistance to the passage of the current.



ELECTRIC FIVE O'CLOCK TEA.

For many purposes, such as heating houses and cooking food, such temperatures as, we have seen, are attainable, are quite undesirable. We need in such cases more heat in quantity, but less in intensity ; that is, we want it less localized and more distributed. This is readily obtained by distributing the resistance. Returning to the filament of the incandescent lamp for an illustration, if the filament were made ten times as long, but its conductivity per unit of length were so increased that, with its added length, it still presented the same resistance to the flow of the current, then the same quantity of heat would be generated, but, being distributed over ten times its length, its intensity would be only one-tenth as great and the filament, though it would be hot, would not be hot enough to be luminous.

Advantage is taken of this principle of distributing the heat by distributing the resistance of a conductor, to apply the electric current to domestic purposes, such as warming the rooms of houses, heating cook stoves and broiling beefsteaks, and electrical heaters, adapted to all these domestic uses and many others, are now articles of regular manufacture.

The plan adopted in all cases is essentially the same, and consists in employing considerable lengths of conductor, having a total resistance properly adapted to the current to be used, and so wound or folded back on itself as to be contained in small compass. A favorite method is to imbed such a wire either in a flat coil or in zigzag or corrugated lines, in a thin sheet of cement or enamel, which may be strengthened by a sheet of cast-iron or steel. Such a plate, when the proper current is turned on, becomes quickly heated, and may be used for all purposes for which the top of a coal stove is suitable, or by lining a box or enclosing a space by a number of such plates, it may do duty in the most perfect manner as an oven, and roasts may be cooked or bread baked in it, both quickly and cheaply.

If, instead of applying the cement with its wires to a plain piece of iron as above, it be applied to the bottom of a teapot or coffee pot or to a frying pan, we have those utensils prepared to

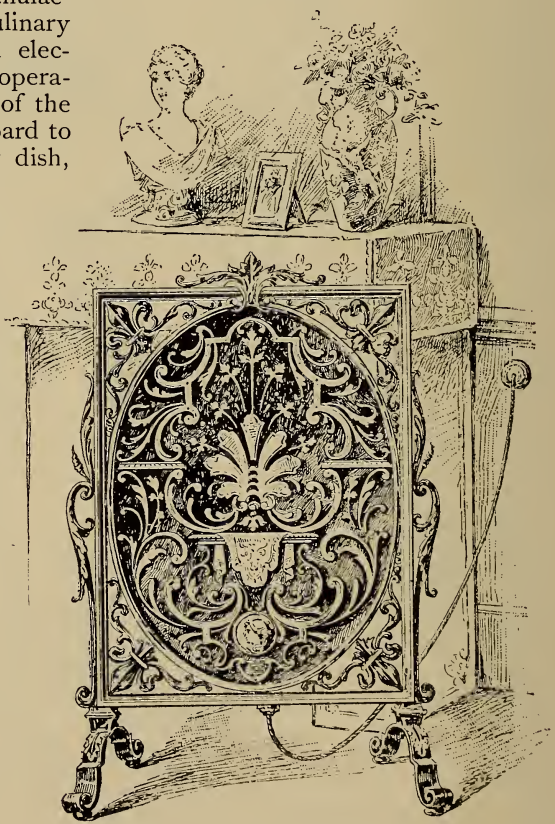
be brought into use by attaching the two ends of the wires by means of flexible electrical conductors to electric light fixtures. The heat, too, may be regulated to a nicety by turning on more or less current by means of a device provided for the purpose. The exact temperature required may thus be both attained and maintained, and no heat need be wasted, for when the cooking is completed the current may be turned off until heat is needed again quite as easily as gas is turned off from burners when light is no longer required.

At the World's Fair at Chicago in 1893, electrical cooking utensils were shown in considerable variety by English, German and American manufacturers. One firm showed a culinary department fully equipped with electrically heated utensils in daily operation. On a table at the front of the exhibition booth was a switchboard to which were attached a chafing dish, stew pan, tea kettle, coffee pot, broilers, griddles and all the other paraphernalia necessary for a first-class kitchen.

Here water boiled in thin glass dishes upon a thin metallic disc with no apparent means of heat generation, but the heat, nevertheless, was real and under the most perfect regulation imaginable. Welsh rarebits were made in a chafing dish, steaks were broiled to a turn on the broiler; coffee, tea and chocolate were brewed as only an expert can brew them; ironing was done, and other practical illustrations were given of the manifold uses to which electricity may be put by the housewife.

But perhaps the most interesting feature in this exhibit was the electrical bake oven, which was in almost constant use. This consisted simply of a wooden box, about two feet and a half long by a foot and a half high, and of the same width. On two sides and at one end it had doors in which were large glass windows, through which the progress of events could be observed. Except where the windows were, the interior was lined with asbestos. The top and bottom were composed of heating plates, and there were cleats around the sides, so arranged as to permit of the introduction of additional plates in various positions, when desired, so as to distribute the heat exactly as might be required for each particular dish.

Three of these plates were normally in position, but each was separately controlled, so that, without opening the doors, one or all could be thrown in or out of action at will. To assist observation, the interior of the oven was illuminated by four incandescent lights, so that everything that was going on within could be plainly



A PORTABLE ELECTRIC RADIATOR.

seen from without, and a mercurial thermometer kept one advised of the temperature at which the results were being accomplished. There was almost no radiation of heat from the oven, and as one watched the rib of beef roasting or the loaf of bread baking within the illuminated interior, it was difficult to realize that cooking was going on. The impression given was rather that of a somewhat odd looking ice chest, into which these things had been placed for refrigeration.

This would certainly seem to the layman to be an ideal method of cooking, and this idea is not controverted by those who have tried it. In addition to the utensils actually in commission, many others were shown, including a collection of irons of various kinds, such as sad irons, goose irons, polishing irons, all made so that they could be connected with the electric light current and used at will, glue pots, wash boilers, and that my lady's boudoir should not seem neglected, samples of electric curling irons were shown. In another part of the display were car heaters of various descriptions and portable stoves and radiators,—all adaptations of the same principle.

So much for the display of electrical cooking and heating appliances at the World's Fair. Of course this list is capable of almost indefinite extension. Some of the directions in which this extension is being pushed are indicated by what is being done in London, where it is said that some of the electrical supply firms are taking very sensible and practical steps to enable the public to readily enjoy the advantages of electrical heating. They are not only lending out electrical cooking stoves to customers, but are prepared to supply a separate meter and charge half rates for cooking, which, they claim, they can afford to do inasmuch as the consumption would take place chiefly during the daylight hours when there would be but little demand for current for lighting purposes. Besides these stoves, they are furnishing breakfast cookers, in which eggs and bacon may be cooked on the breakfast table; electric plate warmers, which are being ordered by the London clubs, for they can be kept in the dining room without any offensive smell; electric foot warmers and ornamental screens, which act as radiators of heat and warm the room; electric curling iron heaters for the ladies, and electric shaving mugs for the men.

As regards the extent to which these electrical appliances have come into use, about all that can be said is that as yet it is limited. Many of the cars on the electric railway lines are now heated in winter entirely by electrical heaters, placed beneath the seats where they take up no useful room, and their use for this purpose is rapidly increasing; but for domestic purposes—cooking or heating of residences—less progress has been made. For these larger uses, as well as for illumination, current must be brought into the houses from street mains. It is out of the question at present to consider primary batteries as a source of current for either of these purposes.

As to the actual cost of electrical heating the following data are the most reliable at present obtainable. They have been translated into equivalents of 16-candle power electric lamps, the cost of an electric lamp being about 1 cent per hour. One pint of water can be brought from 60° F. to the boiling point at the cost of two 16-candle power lamps for 1 hour; or, by the use of the equivalent of 5 lamps it can be made to boil in 12 minutes; or, by the use of the equivalent of 16½ lamps it can be made to boil in 3.7 minutes. Four or five cutlets can be fried, including the time required for heating the pan, by employing the equivalent of 5 lamps for 12 minutes. For the electric oven one authority states that the equivalent of 18 lamps will heat it from 53° F. to 120° in 5 minutes, to 256° in 10 minutes, to 356° in 15 minutes, and to 437° F. in 20 minutes.

From this it will be readily seen that electrical cooking is considerably more expensive than present methods, and must still be considered in the light of a luxury, but it is a luxury in more ways than one. It would be a luxury,

indeed, if the dirt and heat attendant upon the coal stove could be done away with, and when this luxury ceases to be too expensive, as it will when methods of generating electricity are cheapened, it will be widely adopted and more thoroughly appreciated. Then may we expect the culinary art to become an exact science, and with its elevation to that place will dyspepsia become but a memory of the past, a ghost that has been successfully laid, and that part of mankind which is said to be most easily reached through the stomach will be appeased, the millennium will be at hand and peace will reign supreme.

## Current Topics.

DECIDEDLY the most interesting and curious of recent chemical products is calcium carbide, or calcium acetylide as it might be called from a theoretical-chemical point of view. It was first described by Wöhler, who made it by strongly heating an alloy of zinc and calcium with charcoal, but it is now turned out on a considerable scale by heating a mixture of dry lime and coal dust in an electric furnace. In other words, an immense electric current, such as is used in the production of aluminium, for example, is passed through the mixture, whereupon a part of the carbon takes the oxygen from the lime and carries it off as carbon monoxide gas, while another part of the carbon combines with the calcium thus set free. Analogous bodies, all of which are explosive, are formed with copper, silver, sodium and potassium. The noteworthy feature of the new compound, which is of a greenish-gray color and somewhat resembles the mineral serpentine, is that, on contact with water, it develops acetylene, the hydrogen of the water combining with the carbon to form this gas, while the oxygen of the water forms lime by combination with the calcium.

FROM information, kindly given by Dr. Henry Morton, of Stevens Institute, it appears that the calcium carbide is claimed to be obtainable at a cost of £3 or £4 a ton. If this be so, the compound would promise well as a source of illuminating gas since acetylene gas burns with a very luminous flame. In a country-house, for example, it would be necessary only to have a closed vessel, charged with the calcium carbide and

provided with an automatic stop-cock, which would allow water to flow in as required ; then, the piping of the house being connected with the closed vessel and with a small gas holder to regulate pressure, the light supply would be complete and automatic. A piece of carbide of calcium may be held in the hand and sprinkled with a few drops of water. A gas will then be developed which may be lit with a match and will continue to burn as long as a few drops of water are sprinkled on the substance from time to time.

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THAT digestion and food assimilation by the human body is really a species of combustion as, of course, nearly everyone knows, and that the human stomach may be well likened to a furnace in which certain quantities of fuel must be burned to accomplish certain purposes, has received a new and very interesting demonstration by M. Pictet, who of late has carried out a series of striking low-temperature experiments. The most recent of these related particularly to heat radiation from the human body. As described before the French Academy of Sciences, he placed himself, well protected with furs, in a huge tube of which the temperature could be reduced to as low a point as —130 degrees Centigrade. His head alone remained outside, since the breathing in of air as cold as this would have been seriously injurious. At a temperature of —50 degrees the furs were found to arrest radiation, which fact explains the resistance to cold exhibited by polar animals. Below —70 degrees the heat passed through the furs, but no special sensation of cold was felt. Nature at this point came into action by exciting internal phenomena of combustion and digestion, so that in about four minutes the sensation of hunger was experienced. In fact, M. Pictet asserted that in this way he was cured of dyspepsia from which he had suffered for several years, eight sittings in a tube cooled down to —110 degrees having sufficed for the purpose. We have here, therefore, a decidedly novel exhibition of thermodynamic functions going on within our bodies.

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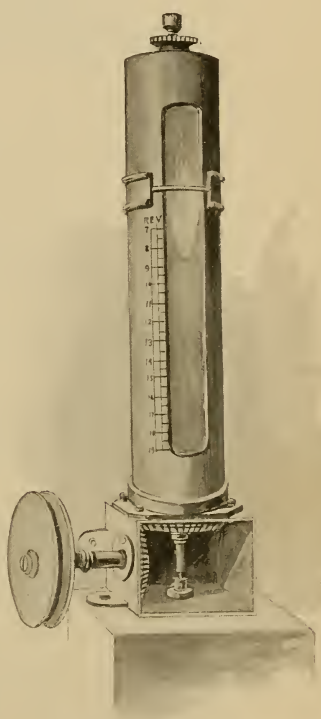
AN inquiry which was recently made in one of the electrical journals for a speed indicator which would enable revolutions per minute to be read off at once without necessitating the use of a watch, brought out, as was to be expected, several replies, telling of a number of devices of this kind now on the market and in successful use. Nearly all such indicators, however, are rather delicate in structure and correspondingly costly, making it all the more interesting to note quite a simple and cheap instrument which was brought out in England a number of years ago to accomplish the same purpose, the inventor being Mr. Killingworth Hedges, of London, who called the contrivance a "Vortex" indicator. The name was a very appropriate one and quite descriptive in itself. The apparatus consisted simply of a removable glass tube, revolved in a metallic case which was furnished on the outside with a sliding ring. The tube was partly filled with water, and when revolved the latter had a tendency to creep up the sides of the glass, carrying the air down in a parabolic form which became more and more elongated as the speed increased. The bottom of the air bub-



A NOVEL SPEED INDICATOR.

ble, if it may so be termed, gave the speed which was easily determined by getting two fine wires on the sliding ring in line, the revolutions being marked on the case. The depression in the water column was always proportional to the speed, so that the calibration of the instrument was a simple matter.

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Coal cargo dangers and how to guard against them have been made the subject of a useful circular of instructions, prepared a short time ago by the British Board of Trade and intended as a guide for ship surveyors. In it, ventilation, as a means of preventing the accumulation of explosive gases, has received some prominence, and particulars are given as to the size and disposition of ventilating pipes and cowls, and of the danger of carrying naked lights below decks, especially in compartments in which gas-laden atmospheres are likely to be found. The one criticism that might be made of the instructions is that more could have been said with advantage of the importance of ventilation, which, after all, is practically the only safeguard against gas explosions. A lamp, or a candle, or even a lighted match, will find its way into a dangerous compartment sooner or later despite all precautions and rules, and blow up the ship. As to safety lamps, while commonly adopted on petroleum tank steamers, they are dangerous because they cannot, or will not, be treated with that care and maintained in that excellent order which rigid supervision and legal enactment enforce in coal mining operations.

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Chief reliance must, therefore, as stated, be placed in ventilation which will either dilute the gas below the exploding point, or sweep it altogether out of the ship. Natural ventilation, however, will not answer, nor will the crude methods of using wind sails meet the requirements. The conditions may be fairly likened to those encountered in petroleum tank ships in which these expedients have been found decidedly lacking. Simply forcing air in at one end of a compartment and allowing it to escape at the other would also not give the desired efficiency of ventilation, since in every enclosed space there are, unavoidably, pockets and inaccessible corners, in which gases collect, and would remain undisturbed by ordinary, direct air currents. What should be supplied would be a system, modeled, in the main, after the currently practiced systems of coal mine ventilation, by which diffusion of the streams of air would be secured and every nook and corner of a compartment would be reached. This practically means an intelligent disposition of deflectors to divert the air supply from a fan into channels which it would not otherwise seek. The additional expense which a ventilating outfit of this kind would entail over that of a system of simply and indiscriminately forcing air through a ship would be comparatively trifling, since only light air pressures would have to be dealt with, and thin sheet metal plates would satisfactorily answer the purpose of deflectors. The principal reason, no doubt, why, as a general thing, efficient ventilating systems are not used, is a lack of appreciation of the dangers of coal bunker gases, and of the shortcomings of the ordinarily adopted safety measures.

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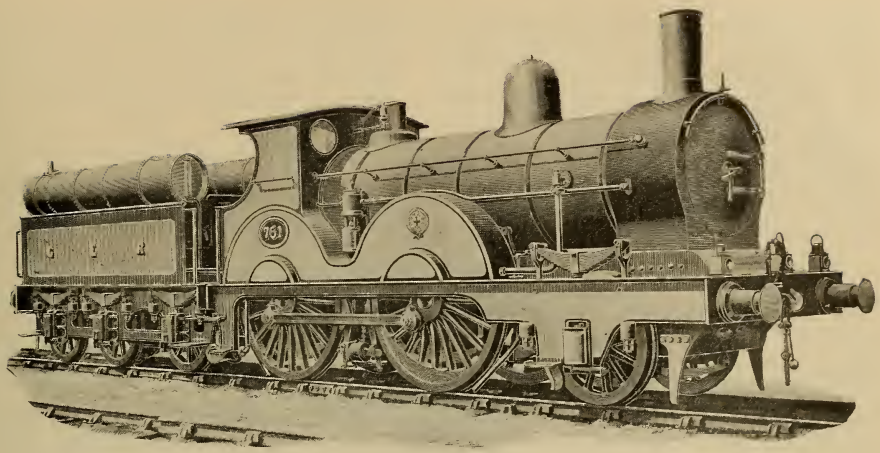
Mr. James Holden, the locomotive superintendent of the Great Eastern Railway, some time since designed an express passenger engine and tender for liquid fuel burning in which the whole of the liquid fuel apparatus is so arranged that it does not at all interfere with the use of the locomotive as an ordinary coal-burning engine. Indeed, the gradations from all oil burning to all coal can be rung on one trip if required; that is to say, the engine might start out, burning all liquid fuel, and, supposing the supply to run short, could gradually take to coal burning until only solid fuel was consumed; or, the change could be made at once if necessary. A comprehensive account



LIQUID FUEL EXPRESS LOCOMOTIVE ON THE GREAT EASTERN RAILWAY, ENGLAND.

of the engine, with many illustrations, was recently published in Engineering, of London, and from this the annexed view was reproduced and the appended particulars have been taken. The liquid fuel is carried in the tanks shown on the top of the tender, and a steam pipe coil in these, for use in cold weather, prevents the oil from becoming too thick to flow easily. The oil injectors, which, of course, are worked by steam, are used also, by means of a special connection, to exhaust the air for the vacuum brake which is employed in addition to the regular Westinghouse brake installation, and when the vacuum brake is not in service, hot air can be fed to the burners from heating pipes arranged in the smoke-box.

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AROUND each injector nozzle a ring blower is arranged, consisting of an annular chamber pierced with holes. From these steam issues, and in this way the oil injected is very thoroughly sprayed and very rapid combustion is secured. No extra fire-brick is required in the fire-box beyond a wall beneath the customary brick arch. The usual practice in working on Mr. Holden's system of liquid-fuel burning is to keep the bars of the grate covered with about 3 inches of solid fuel. This may be coal, coke breeze or a mixture of coal and chalk, or coal and broken fire-brick may be used. The combustion of this solid fuel is checked by partially closing the dampers, the necessary air for the combustion of the oil fuel being introduced by the action of the ring blowers above the solid fuel base. Speaking of a run recently made on the engine, the writer of the article in Engineering says :—"The trip was made without a stop, the steam pressure remaining absolutely steady throughout. During the whole run of 79 miles, the fire, that is, the coal fire, did not require attention more than half a dozen times, and then only to put a little coal where it was getting somewhat thin, the fireman's berth being really a sinecure."

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WHAT would seem to be a noteworthy competitor of the method of rail-joint welding, as now practiced by several electric street railroad companies in the United States, is the joint casting process, operated by the Falk Manufacturing Company, of Milwaukee, Wis. Joining two rail ends by pouring molten metal around them seems, indeed, a simple enough operation, and, yet, the results which have attended the practice appear to have been of a most satisfactory kind. The outfit complete is shown in one of the accompanying illustrations, and consists, in the main, of a cupola and a small blow-

ing engine and boiler carried on special trucks, the cupola being so hung as to remain in proper position even though the wagon may be standing on a heavy grade. The rail ends to be joined are carefully cleaned, and. if there be much space between them, a thin shim is inserted. Then a couple of cast-iron moulds, lined with non-conducting material, are clamped in position as indicated in the second of the illustrations, and molten iron, tapped from the cupola, is poured in, effecting a union so similar to that which takes place through a good welding operation that the term "cast-welding" has been applied to the process. A plate of iron is laid over the joint on the rail heads, so that when the iron attempts to rise there it is chilled.

A CAST-WELDING OUTFIT.

POURING A JOINT.

A CONSIDERABLE number of joints may be made at one time, but as the heat of the poured metal causes appreciable expansion of the rails, it is advisable to operate on only every other joint, say, at one time, taking the others in hand after the rails have again become cool. It is interesting to note also that while the process, as just briefly described, produces practically a welded joint, the heat of the molten metal raising the two rail ends to a welding temperature, the Falk Company is prepared to make still another form of joint in which the rails, before casting, are painted with a preparation which prevents the welding action. As a result, a solid mechanical joint is obtained, freely permitting expansion and contraction of the rails. It is this latter joint which would seem to commend itself to much wider use than simply in street railroad service.

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IT might have been thought that metals under stress would be more liable to corrosion than when in their normal state. Experiments made by Mr. Thomas Andrews, however, and

detailed in a paper recently presented at one of the meetings of the Institution of Civil Engineers of Great Britain, have shown that exactly the reverse is true, providing that "strained" metal is considered separately from "unstrained" metal. When the strained metal is in galvanic circuit or combination with the unstrained metal in any solution, an increased total corrosion ensues from the galvanic action consequent on the difference of potential between the two. The reason why the mere fact of a metal having become strained reduces its corrosibility, compared with the same metal in its normal unstrained condition, is found in the results of a series of experiments undertaken some time ago by Mr. Andrews to investigate the influence of stress on railway axles. In that research it was demonstrated that stress, whether tensile, flexional, torsional or of any other kind, considerably alters the physical properties of iron and steel. Stress increases the rigidity and renders the metal harder, also greatly reducing its properties of elongation or ductility, and a higher tonnage is required to break a strained than an unstrained piece. A tensile stress applied to a wrought-iron shaft, producing an elongation of only 2 per cent., increased the tensile resistance 2.66 per cent. Other investigators also have noticed a similar alteration in the properties of metals referable to stress.

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FROM these observations it became manifest that the stresses applied to the metals examined for corrosion altered their structure, rendered them harder in nature, and, hence, less liable, in the strained condition, to be acted upon by sea water, or other waters, than in their ordinary normal or softer condition. The experiments, however, indicated also that an increased total corrosion in excess of the normal corrosibility of the metal occurred in a metallic bridge, vessel, boiler or other structure, from the action of the local galvanic currents which were shown to be induced between "strained" and "unstrained" portions of even the same piece of iron or steel forging, bar or plate. Hence, a strain occurring in a metallic structure, after all, tends, owing to the local galvanic action thus set up, to increase any corrosive forces which may be deteriorating the metal of which it is composed.

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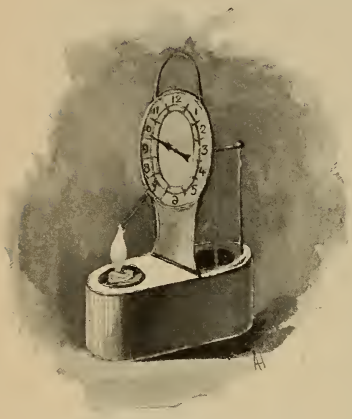
CURIOUS time-pieces recently formed the subject of an article in the French journal La Nature in which a number of illustrations were given of early specimens of the clockmaker's art, not the least interesting among them having been the two lamp clocks shown on this page and the next. One of these was of a kind quite common in the seventeenth century, and consisted of a lamp burner placed at the base of a glass oil receptacle mounted vertically upon a suitable standard. The oil reservoir had attached to it a scale, facing the burner, and showing the hours, beginning at four o'clock in the afternoon, at which time the lamp was to be lighted in winter, and ending at seven o'clock in the morning. The lamp being lighted, the gradually descending level of the oil, as combustion proceeded, marked the hours. The other device,—of later origin, dating back to the beginning of the present century,—utilized the same principle. It consisted of two communicating oil chambers, superposed by a clock dial. In one of the chambers was placed a night lamp to illuminate this dial, and in the other was

A LAMP CLOCK.

suspended a float from a cord which passed around a small pulley. The latter was mounted on a horizontal axis ending in the centre of the dial. The float, of course, descended as the oil was consumed, and carried the index hand along with it, thus marking the hours precisely as in the case already cited. At their best, these timepieces could have had only an indifferent degree of accuracy; yet, they probably served their purpose well, and certainly are interesting at the present time as illustrating some of the expedients adopted by mechanicians of an earlier period.



ANOTHER TYPE OF LAMP CLOCK.

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ANENT the recently mooted question as to the greatest air pressure that men can stand in caisson work, the well-known contracting engineers, Messrs. Sooysmith & Company of New York, who, for years, have made a specialty of difficult foundations and tunnelling, requiring the use of compressed air, tell us that the full ability of properly equipped and properly behaved men, under the most favorable conditions, to resist caisson disease, has never been tested. The highest working pressures recorded have been close to fifty pounds per square inch; but with extreme care in the selection of men, and corresponding care on the part of the men, it is very probable that this limit may be considerably exceeded. For the average pressure-man under average conditions, the top limit may be placed at about forty-five pounds, the time of working varying from four to six hours per shift, according to conditions. In the cases where higher pressures might be used, the shifts for the men should be restricted to two, of two hours each, separated by a considerable interval. As an example of heavy pressure work, under favorable conditions as to ventilation without very bad effects on the men, Messrs. Sooysmith & Company had an experience with a work on which men were engaged in six-hour shifts, separated into two parts by half-hour intervals for lunch. This work was excavation in open, seamy rock, carried on for several weeks under about forty-five pounds pressure.

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THE character of the material through which the caisson is being sunk, or upon which it may be resting at any time, bears quite largely upon the ability of the men to stand the pressure necessary to hold back the water at that point. If the material be so porous as to permit a considerable leakage of air through it, there will naturally result a continuous change of air in the working chamber, and a corresponding relief of the men from the deleterious effects which are produced nearly always by over-used air; in other words, a system of ventilation is kept up by the porous material. On the other hand, if the caisson is passing through an impervious substance such as tough clay, ventilation is much obstructed, and the consequent bad effects on the men are very noticeable. As it is usually necessary to carry the highest pressure when the caisson has reached its final position and while the air-chamber is being filled with concrete and sealed up, the worst effects usually result at these times; thus, very often at the time when the pressure is greatest, the ventilation is the worst. As an example, experience has shown that in one known instance at least, during rock excavation at great depths, the leakage of air through the seams and crevices of the rock permitted of the men standing very high pressures. The physical condition of the men is a very important factor in the whole matter. Men who are thoroughly sound organically, and who are not fleshy, can endure much higher pressures than men who have

not these physical conditions. Moreover, the degree to which pressure-men observe hygienic rules, preserve regularity of conduct and abstain from dissipation, affects largely their capacity to endure the effects of compressed air. The extent also to which pressure-men adhere to the rules for entering pressure, for conduct while at work, for exit to the ordinary atmosphere, and for behavior immediately after coming out, influences their physical sensitivenes to hese effects.

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It may not be uninteresting, in connection with the foregoing, to give substantially the rules which Messrs. Sooysmith & Company have formulated for the guidance of their employees and which, if strictly obeyed, will tend to considerably lessen the danger of having the "bends" or other caisson disease. To begin with, all men having heart trouble or who are subject to dizziness or epileptic attacks, or who are not in good health generally, or who are particularly stout, are advised not to work in a caisson. In coming from or going to a caisson, the men should go direct from the shaft to a warming-house, or from the warming-house to the caisson, as the case may be. The warming-house should not be left until the foreman gives notice that the caisson can be immediately entered. After entering the warming-house, workmen should under no circumstances whatever sit by an open door or window, or where cool air will strike them. If, on coming from a caisson, a man is in any way affected by the "bends" he should lie down as close as possible to a stove and be covered with a sufficient amount of clothing to produce perspiration as quickly as possible. Hot applications should also be made to the parts most affected by pain. Half an hour should be spent in the warming-house after coming out of the caisson, and, before leaving the former, the body should be rubbed thoroughly dry with a towel, and, if possible, the clothing should be changed. Men must not go into a caisson after drinking intoxicating liquors, nor must any be used during working hours. A caisson, too, should never be entered with an empty stomach, and a meat diet should be used as far as possible. Warm coffee should be freely taken. On coming out, extra clothing should always be put on and exposure to cold avoided. Exercise as little as may be during the first hour after coming out, when pressure is heavy, and lie down if possible; take at least eight hours sleep every night and see that the bowels move every day. Never enter the caisson if at all sick. These rules are based upon the results of many years of experience in pneumatic work and represent probably the best known means of protecting men against the dreaded caisson afflictions.

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Ropes *vs.* belts for power transmission has for many years been a subject of international interest and discussion. Belt driving has been generally regarded as distinctively American, and is almost exclusively followed in the United States, while rope transmission has been correspondingly accepted as typical of European, and more particularly English, practice, and quite properly so considering the extent to which it has been applied in English mills and manufacturing establishments generally. Both systems, of course, have their drawbacks as well as advantages. As a matter of fact there is very little available in the way of experimental data to show which of the two is really the more desirable. What the relative efficiencies of rope and of belt driving are yet remains to be determined. It has been asserted that ropes absorb about five per cent. more power than belting of equivalent transmitting capacity, and that in many instances this represents a very modest estimate of the loss in question. In many cases the loss is brought about by "over-roping" an engine, the power absorbed by the transmitter being in this way very easily allowed to assume undue proportions. The use of ropes of large diameter, of

pulleys too small in diameter, and with imperfectly finished grooves all tend to augment this loss. The loss due to bending the ropes around pulleys and straightening them again when released, obtains in both belt and rope driving, but its amount is undoubtedly greater in the latter method of transmitting power. On the other hand, rope driving has the great advantage of almost entire freedom from risk of absolute break down. It has been previously pointed out in these pages that when a rope shows symptoms of giving way,—and ropes always give readily apparent symptoms of weakness long before they break—the weak rope can be removed in a very short space of time and another one put in its place. The width of pulleys for ropes is generally rather less than for belts transmitting the same power, though the grooved pulleys cost more than plain ones. Still, making allowance for this, the total cost of ropes and grooved pulleys for transmitting a given power has been placed at less than half the cost of leather belting and plain pulleys. Notwithstanding these and other advantages claimed, more or less correctly, for rope gearing, American engineers still cling to belt transmissions, and a rope-driven plant is now almost as much as it was a dozen years ago, an object of special interest, if not of curiosity, in the United States. The experiments which the Industrial Society of the North of France proposed, a few months ago, to carry out at Lille with the view of practically determining the relative efficiencies of the two systems ought, therefore, to be of decided interest to the engineering profession, and may be expected to go a great way in settling the main points in this long-standing question.

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To what extent machinery and improved processes have cheapened the cost of at least one line of manufactures is shown by a striking bit of figuring in a recent issue of The Iron Age. It was prompted by a remark, made a short time ago by William Garrett, the inventor of the wire rod mill bearing his name, to the effect that "wire nails are sold so cheaply that it is estimated that if a carpenter drops a nail it is cheaper to let it lie than to consume the carpenter's time to lift and use it, and it is claimed by good authority that one keg out of five is never used but goes to waste." Assuming that it takes a carpenter 10 seconds to pick up a nail which he has dropped, and that his time is worth 30 cents an hour, the recovery of the nail, according to The Iron Age, would cost 0.083 cent. There are 200 sixpenny nails in a pound, which is worth 1.55 cents. This would make the money value of the individual nail 0.0077 cent; or, in other words, it would not pay to pick up ten nails if it took ten seconds of time, worth 30 cents an hour, in which to do it.

FROM A PHOTO BY MAULL & FOX, LONDON.

Hiram S. Maxim

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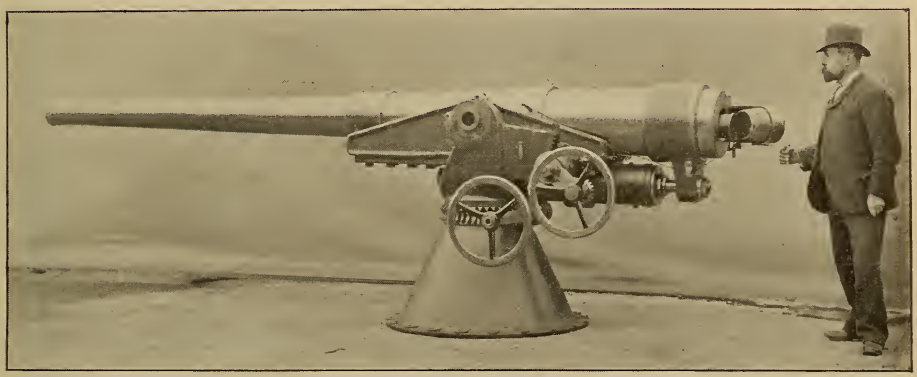
# CASSIER'S MAGAZINE.

VOL. VII. APRIL, 1895. No. 6.



THE IMPROVED MAXIM 45-POUNDER, MADE IN ONE PIECE; 25 SHOTS A MINUTE.

## SOME FEATURES OF THE INVENTIVE CAREER OF HIRAM S. MAXIM.

*By J. Bucknall Smith.*

PROBABLY no name is more deservedly and widely familiar to those engaged or interested in the ramifications of mechanical science than that of Hiram S. Maxim, although perhaps, of late, some may have become acquainted with his name and attainments only in connection with his experiments in mechanical flight. Many persons, however, will remember his distinguished achievements in automatic machine guns and improved artillery,

J. BUCKNALL SMITH is well known to many readers on both sides of the Atlantic as an engineer and author of good reputation. Having traveled extensively in the exercise of his profession, his experiences extend to all parts of the world. As a specialist on cable traction and allied work his name is familiar to many, and his text books and contributions on various technical subjects have been much sought after. Mr. Smith enjoys an intimate acquaintance with Mr. Maxim and has had exceptional facilities for the collection of data concerning him. These, in part, have been used in the preparation of the article in this issue, which, with all that has of late been said and written about the great inventor has a new and peculiar interest. Few of the illustrations here given have ever before been published, and the article itself touches upon many points in Mr. Maxim's career which have hitherto been known to but a few.

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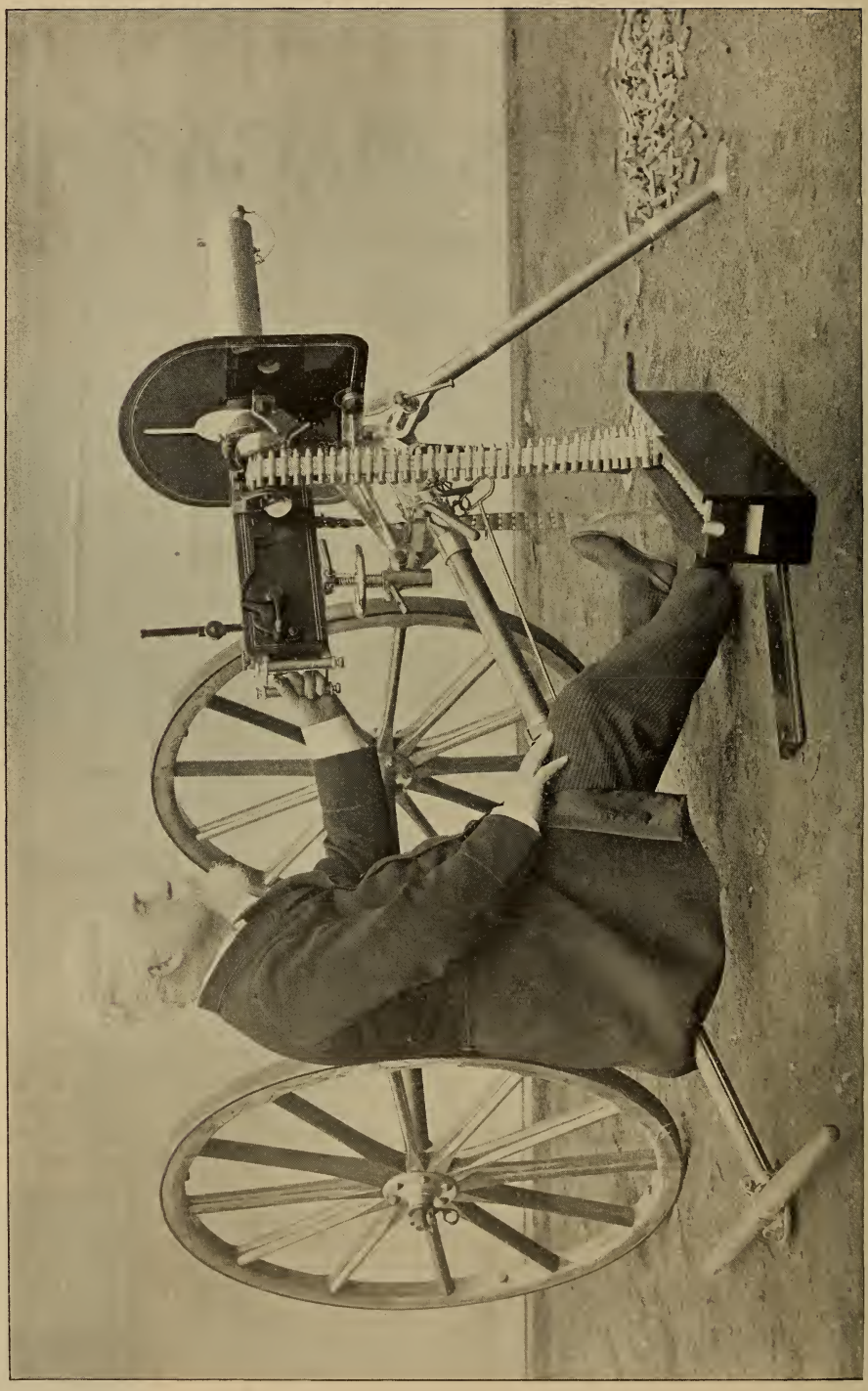


SPECIAL AUTOMATIC MAXIM GUN, MADE FOR THE SULTAN OF TURKEY; 770 SHOTS A MINUTE.

whilst another, and perhaps older, section of the community may recollect the important parts played by the now famous inventor in the early days of electric lighting, some time before the name of Edison was practically identified with the industry.

For originality and versatility Mr. Maxim certainly occupies a unique position in the inventive world, not only having earned for himself a pre-eminent reputation as an engineer and mechanician, but having figured conspicuously in branches of the electrical and chemical sciences with marked degrees of success.

MAXIM'S HOME AT BALDWIN'S PARK, BEXLEY, ENGLAND.

His parents, who were of French extraction, were among the earliest settlers in America, and resided in Sangerville, a small town in Maine, when, in 1840, he was born. As the subject of aerial flight claimed the attention of his father many years ago and his brother, now in America, has given birth to many inventions of importance, it is likely that Mr. Maxim inherited his inventive proclivities to some degree, but his success has been brought about chiefly by diligent study, keen observation and persistence of purpose. No difficulties or accepted orthodox principles have ever deterred him from assiduously and resolutely pursuing his own convictions and methods of attaining the object in view, and, similar to a legion of great and successful men, he may be appropriately described a "self-made" man and the designer of his own fame and fortune.

As a youth, he attended an ordinary local school until he was about fourteen years of age, when he was apprenticed to a carriage builder. But soon afterwards he entered his uncle's engineering works at Fitchburg, Mass., later gaining experience with a philosophical instrument maker, and then at a shipbuilder's. In his spare moments he was a diligent student, always striving to master the principles which underlaid the subjects of his employment, and while yet a school boy he doubtless acquired some rudimentary initiation into and taste for mechanical work from an insight into his father's woodworking factory and grist-mill; but it was not until his uncle took him in hand that his education in the prop-

erties and uses of metals really commenced.

When quite a lad, he began his inventive career by devising an automatic mouse-trap of a novel description—a modest beginning it is true, but that effort was speedily followed by an automatic gas headlight for locomotives which, for a time, was used on some of the American railway systems, though the contrivance was ultimately discarded owing to objections raised against the use of gasoline.

It is not intended to attempt to define the very numerous patents which have been granted to Mr. Maxim for his multifarious inventions in the United States or England, for such a description would comprise a lengthy list of perhaps a monotonous character. The writer will, therefore, confine himself to a reference to some of Mr. Maxim's inventions which have either been adopted in a practical way, or have served as important stepping stones to others in working out more or less revolutionary ideas of their time.

MAXIM'S CAVALRY GUN; WEIGHT, 30 LBS.; 700 SHOTS PER MINUTE.

Towards the close of 1871 he was granted a patent in America for a gas generating apparatus which was largely used in the States. Some of the machines furnished as many as 10,000 lights each, and were temporarily adopted in the New York Post Office during a controversy with the city gas companies. Soon after, he obtained a patent for a steam trap or valve which embodied a principle recognized by many of to-day as being difficult to excel, and which is still a standard type of valve.

About two years later he perfected an invention for an automatic fire extinguisher or sprinkler, the contrivance being so arranged that in case of fire the water in the basement was automatically turned on, while carbonic acid gas was generated in a reservoir. It was not, however, until a short time before the expiration of the patent that insurance companies began to advocate the employment of such extinguishers, although since then many automatic sprinkler devices have been adopted. Like innumerable other inventors, Mr. Maxim, it would seem, was a little too premature to make his idea profitable.

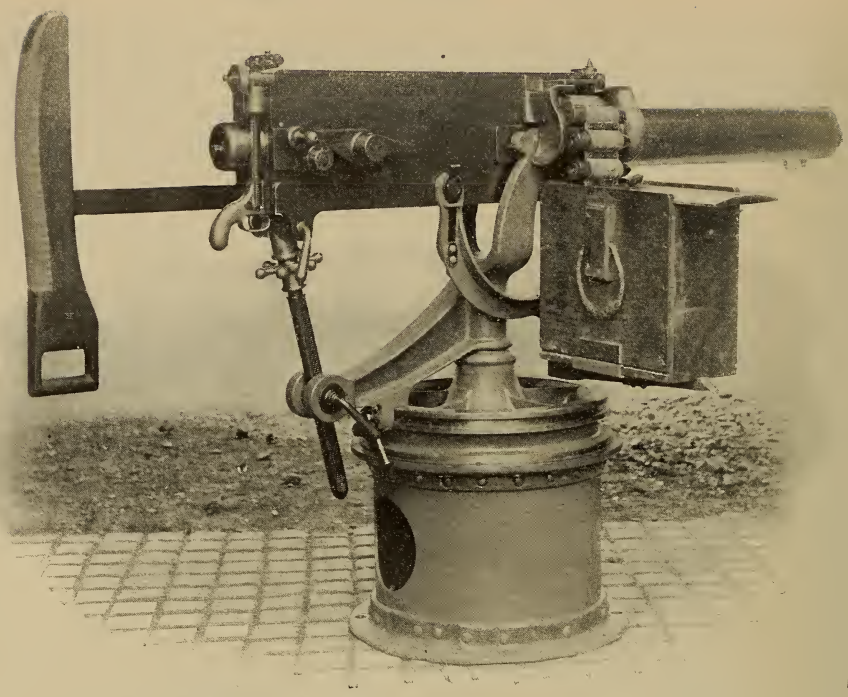
In 1874 he successfully turned his attention to designing automatic steam pumping engines for domestic purposes, using gas as a fuel, being prompted in this by the necessity in New York City of a convenient apparatus for pumping water from the street mains into tanks, as the water supply was inadequate to reach the higher floors of buildings. Soon afterwards, improved feed water heaters, gas-making apparatus, steam and vacuum pumps, engine governors, gas motors, liquid meters and regulators, apparatus for

FROM A PHOTO BY THE LONDON STEREOSCOPIC AND PHOTOGRAPHIC CO.

MR. MAXIM EXPLAINING TO MR. SMITH AND OUR EDITOR HIS LATEST AUTOMATIC GUN, RECENTLY DESIGNED FOR THE EMPEROR OF GERMANY; 700 SHOTS A MINUTE.

carburetting air for illuminating purposes, etc., bearing the distinguished inventor's name, appeared in the markets and met with more or less success.

As early as 1878 we may find Mr. Maxim's name recorded amongst the United States patents in connection with improvements in electric lamps and appurtenances of various descriptions, speedily followed by the grant of prerogatives for improved dynamo-electric machines, the production of lamp carbons, regulating mechanism, the introduction of rarified hydrocar-



A LARGE MAXIM GUN, AS USED IN THE FRENCH AND RUSSIAN NAVIES, 300 SHOTS A MINUTE.

bons into incandescent lamps, processes and apparatus for exhausting the air from electric lamps and demagnetizing carbon holders, secondary batteries, watches and others.

Mr. Maxim recognized, from the commencement, the virtues of carbon conductors for incandescent lamps, as brought out by Sawyer, Mann and Swan, and immediately set about to devise commercial processes for the efficient production of such carbons, followed, within a couple of months, by his important invention of displacing the air in the globes by the introduction of gasoline, which was afterwards expelled by heat and exhaustion. This patent really constituted the basis of the afterwards universally used "flashing process" in the manufacture of incandescent lamps.

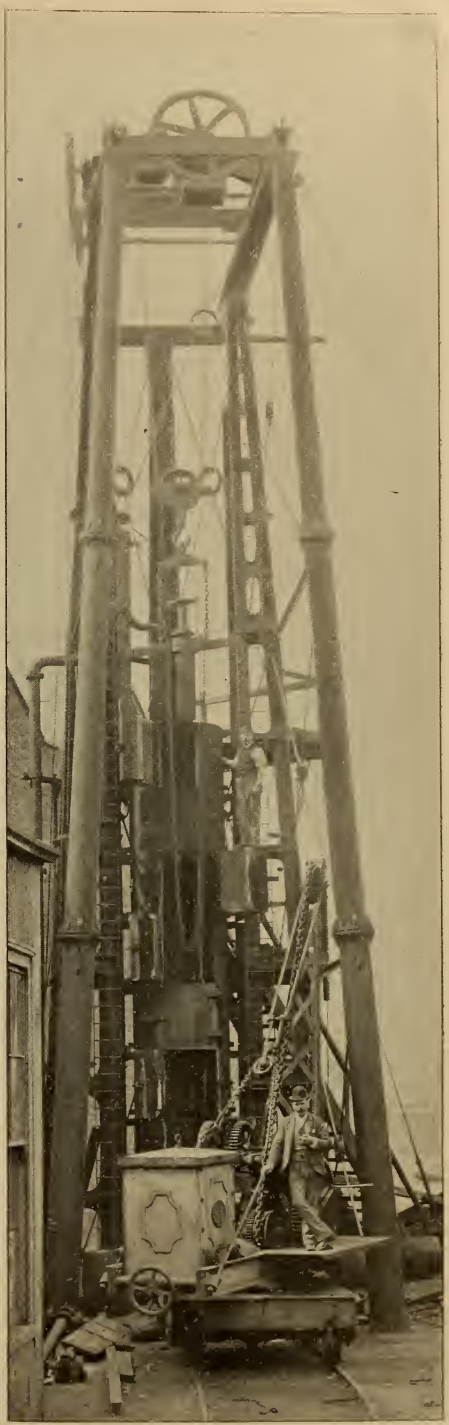
It may not be generally known that Edison did not abandon the platinum conductor in such lamps until after Mr. Maxim had proved the superiority of carbon and had overcome the difficulties associated with its use. During the same year Mr. Maxim devised the first electrical regulator by which the current was controlled by changing the position of the dynamo brushes, and it was the patent for this system which hampered the monopoly of electric regulation in America, then mainly in the hands of Messrs. Thomson, Houston & Co. About the same period it occurred to Mr. Maxim that it might be possible to pass both a positive and negative current through one and the same wire. After careful experiments he ascertained that this could be practically effected, and with a considerable reduction of resistance in the system. Professor Tatem of New York was consulted upon this phenomenon, which was probably the first suggestion of the feasibility of the three-wire system, afterwards profitably pursued by Edison and Lord Kelvin.

Before the close of 1880 Mr. Maxim patented the first arc lamp ever used in the city of New York for open air illumination, and also invented a valuable system of electric lighting regulation

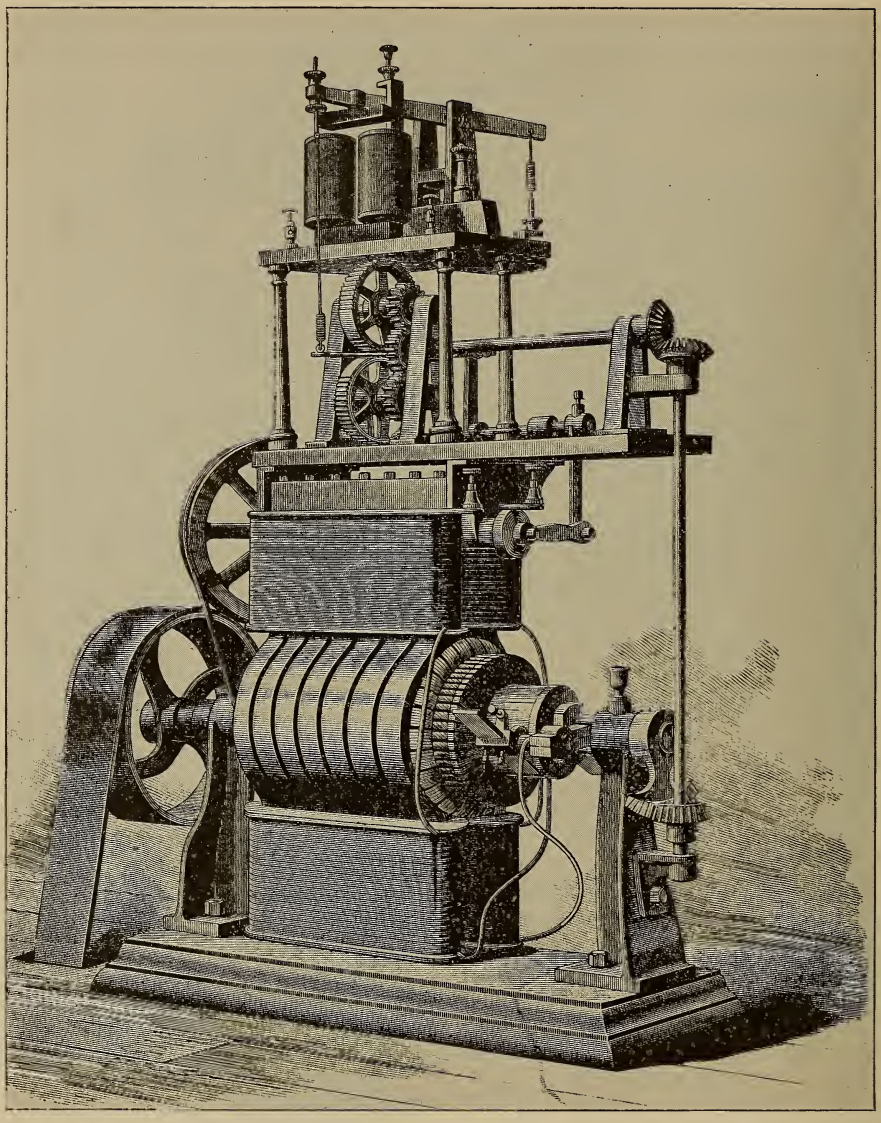
in which the control was effected from the centre of the illuminated district instead of at the generating station. Some time afterwards Mr. Edison found this patent an obstruction to his progress, and even went so far as to endeavour to get it set aside.

The following invention furnishes a good example of the extraordinary versatility possessed by Mr. Maxim and by which he has been able to successfully turn his attention to matters in almost every branch of science. As soon as the manufacture of incandescent lamps became a recognized industry, a great demand developed for the supply of phosphoric anhydride, which was employed for extracting moisture from the gases used in the "flashing" processes. Originally the substance was obtained from Germany at a high price, but by Mr. Maxim's process, patented in March, 1881, the cost was largely reduced and the product was of a better quality. His invention was the means of making the anhydride at the rate of one-half pound per minute, and resulted in a revolution of the earlier methods of manufacture. Six months later he introduced to the electrical world the first incandescent lamp, in which the carbons could be replaced by new ones at pleasure.

Soon after Edison had commenced his experiments with electric lamps, it was said that he had succeeded in making a "practical platinum lamp," and, when his patent was issued, gas shares all over the world temporarily fell in value more or less and brought about almost a panic. A New York paper published a letter stating that Edison's lamp was "simplicity itself" and that it was constructed in such a manner that "overheating is almost impossible," for, whenever the platinum became heated too much, it expanded and shunted the current through a resistance coil in another direction. The alleged invention was broadly claimed, and a great deal was vaguely said about it. Shortly after, however, Maxim's lamp patent of September, 1881, was put into "interference" with Edison's production and proved to be almost the



MAXIM'S APPARATUS FOR ANNEALING CANNON BUILT IN ONE PIECE.



MAXIM'S CURRENT REGULATOR.

identical thing, working in exactly the same manner. In the first instance, as well as in the three appeals, the decision was against Edison, the patent being finally decided in Maxim's favour.

At about this period Mr. Maxim brought out the electric regulator of which an illustration is given on this page, and by this ingenious contrivance it was immaterial how many lamps were on the same circuit at any given time, the amount of current supplied to each being always constant, and, hence, the lights were maintained uniform. This invention was patented in America in 1882, and eventually won for him the distinction of the French order of Chevalier de la Legion d' Honneur.

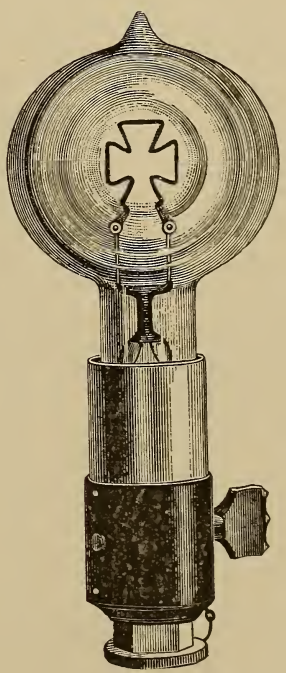
In 1878, when Mr. Maxim first turned his attention to electrical engi-

neering, he was engaged by the United States Electric Lighting Company, and two years after, he first visited Europe with the object of studying electrical progress generally on that side of the Atlantic; but it was not until 1883 that he made England his permanent home. At the beginning, he represented the American Electric Company in London, but at the first leisure he began working out his automatic machine gun, which had been a long-cherished idea.

The now famous gun maker first established works in Hatton Garden, Holborn, early in 1884, where he was soon afterwards visited by the Prince of Wales and the Duke of Edinburgh as well as other numerous distinguished persons. Space will not permit the writer to discuss the difficulties and obstructions which he encountered and ultimately overcame in connection with this invention, but it may suffice to add that by his indomitable application and persistent study he surmounted his troubles with alacrity and soon perfected his idea, so that during a machine gun competition at Hythe, he beat all competitors, his gun, having a total weight of but forty pounds, firing 1000 rounds in 1¼ minutes. After this, he exhibited his destructive weapon in various parts of Europe and accepted many challenges, defeating all comers. In Switzerland, in a contest with a number of different types, there was but one instrument which could be really considered a competitor. It was a double-barrelled affair, weighing about five times as much as Maxim's apparatus, but so defective in construction that after firing a few rounds it became "jammed." Mr. Maxim's gun continued to discharge some seven hundred shots per minute, the bullets being found accurately grouped in the centre of the target while the other competitors had been "firing all over the place."

The Maxim gun was thereafter speedily recognized to be the most deadly instrument of warfare in existence. Since then it has been fired before nearly all the crowned heads and rulers of Europe as well as innumerable military authorities and experts from all parts of the world. The guns were first fired in actual warfare by Sir Francis de Winton during the Sierra Leone campaign, and were also employed by the great African explorer, H. M. Stanley, in his last, famous travels. The success of the Matabele campaign, too, was universally admitted to have been mainly due to the appalling execution done by the "Maxims" which, by the way, may be constructed to fire any kind of rifle or other ammunition.

The salient features of the Maxim guns are the recoiling and stationary elements, the barrel with a rear attachment receiving a backward motion within the fixed breech casing when a cartridge is discharged. A gun metal



MAXIM'S EARLY INCANDESCENT LAMP.

cylinder, containing about seven pints of water, surrounds the movable barrel to keep it cool whilst under fire, about 1½ pints of water being evaporated per 1000 rounds. The recoiling motion, through which the actuating energy is

stored and utilized, is limited to a distance of about one inch, and during this small traverse a crank comes into contact with the breech-casing, causing it to rotate and strike a buffer spring, the energy being transferred to a fusee spring and chain which returns the barrel into its firing position. The crank, likewise, works the breech lock, whilst cams operate the cartridge extracting mechanism. A compression of the lock spring upon the rotation of the crank, actuates levers and a "tumbler" device, so as to cock the hammer, which, upon being liberated from the trigger, fires the gun; but when started or when working automatically, as is the case after the first round, the trigger and tumbler are pulled out of action and in this condition the lock spring, firing pin and "sear" do all the work. The cartridges are fed into the gun by means of a belt which passes through feed blocks operated by a pawl mechanism of a most ingenious nature, and, indeed, the whole machine is a monument of mechanical skill. This automatic principle is adopted in guns up to six-pounders, the vital mechanism in each case being made "self-contained," so as to be readily removed and replaced in the event of any derangement.

It will thus be seen that the gun is entirely automatic in its action, *i.e.*, after discharging one cartridge, by pressing a button, the recoil of the barrel inserts the next charge from the belt, raises the breech lock, cocks the hammer, fires, lowers the block, extracts and ejects the cartridge case, while at the same moment the succeeding charge is being brought into position. This cycle of operations may be mechanically performed in less than one-tenth of a second, thus enabling the unique weapon to vomit a veritable hail of bullets at a speed of 770 shots per minute, or, if desired, at any slower rate. It will be understood that the recoil of a gun is due to the resistance offered to the escaping gases by the bullet or projectile; hence, when it is desired to fire blank cartridges in the Maxim gun, a muzzle attachment is used to throttle the gases and make them perform the functions of resistance. The average price charged for this unique automatic machine gun is £200, and every army and navy in the world, except that of the United States, uses some of Mr. Maxim's guns or improvements in armaments.

It is gratifying to Englishmen to reflect that it was the British Government that first recognized the merits of the Maxim automatic machine gun and adopted the same, and from what has been previously written with reference to the "misappropriations" of his inventions in the United States, readers will not be surprised to learn that Mr. Maxim considers Europe to present a fairer field for the *bona fide* inventor, and he is also of the opinion that the patent laws and practices operate more justly in Great Britain than in America.

Mr. Maxim in a recent interview with the writer regarding some of his inventions, said:—"The automatic gun which I invented in April, 1884, was the first that had ever been designed in the world and I, at the time, took out patents for the various ways that people would probably attempt to get round my invention. I harnessed the energy derived from the discharge of the powder so as to load and fire the gun. This was the first time this had ever been done. The most convenient way that I found of utilizing this energy was through the recoil of the barrel, but I took out a great many other patents for modifications. For instance, I acquired patents on operating the gun by gases escaping from the muzzle, by them producing a vacuum, by the gases working upon a liquid upon a piston, by the elongation of the cartridge case at the instant of firing, by allowing a part of the case to slide backwards inside of the same and in many other ways.

"In fact every possible way in which the gases could be employed was patented. I also took out patents on opening the breech lock in various ways, such as while the gun was recoiling, after it had recoiled, while the gun was returning into the firing position and after

THE EXPERIMENTAL FLYING MACHINE.

MAXIM CARRYING ONE OF HIS FLYING MACHINE ENGINES; WEIGHT, 300 LBS.; EFFECTIVE HORSE-POWER, 180. WEIGHT AND POWER CONSIDERED, IT IS CLAIMED TO BE THE LIGHTEST ENGINE IN THE WORLD.

it had returned. I also obtained protection on storing energy into springs or moving parts, the same being accumulated by the force of the powder and used afterwards to perform part or all of the functions of loading and firing. In that way I covered the ground pretty thoroughly.

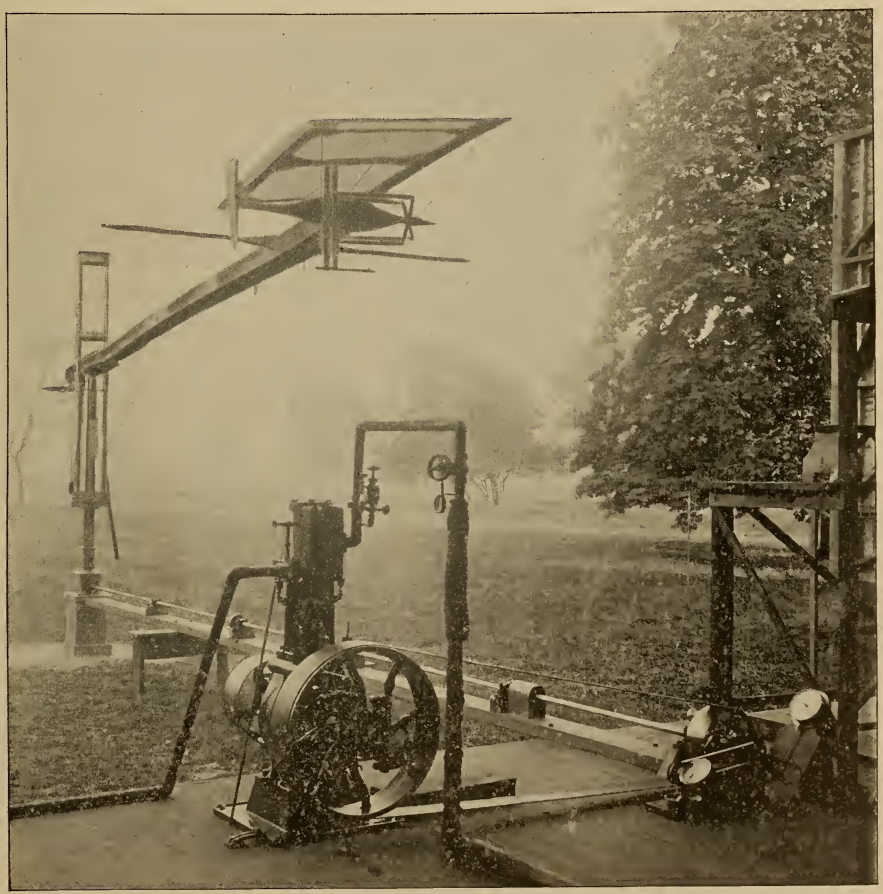
"The gun mounting, shown in my patent of August, 1886, was one of the greatest hits I ever made. In this case the hydraulic buffers and the springs all moved with the gun, giving it advantages over other forms previously devised. The trigger handle and the shoulder piece were attached to the non-recoiling part of the gun the same as the trunnions, the gun (without trunnions) sliding back in the case at the instant of being fired. This was broadly patented in the United States, and the American Government applied it to all their guns, for it was found to be very much better than anything else known. In fact, it was so good that a member of the Bureau of Naval Ordnance induced a subordinate to take out another patent on it so as to use and evade my apparatus without paying a royalty.

"My patent of July, 1889, was the first apparatus ever used in the world for training large guns by electrical means. It was adjusted in such a manner that by pressing a handle or shoulder piece which extended to the rear of the gun in the exact direction that it was desired to train the same, it would operate on switches and turn the gun in such direction that the handle was moved. With this apparatus one can handle the heaviest gun with the greatest ease. In fact, some officers who saw the experiments said that they could shoot a gull on the wing with a 100-ton gun if it were provided with this contrivance. The United States Government are using it extensively in the Navy, without compensation to me, notwithstanding the fact that I was the inventor. There

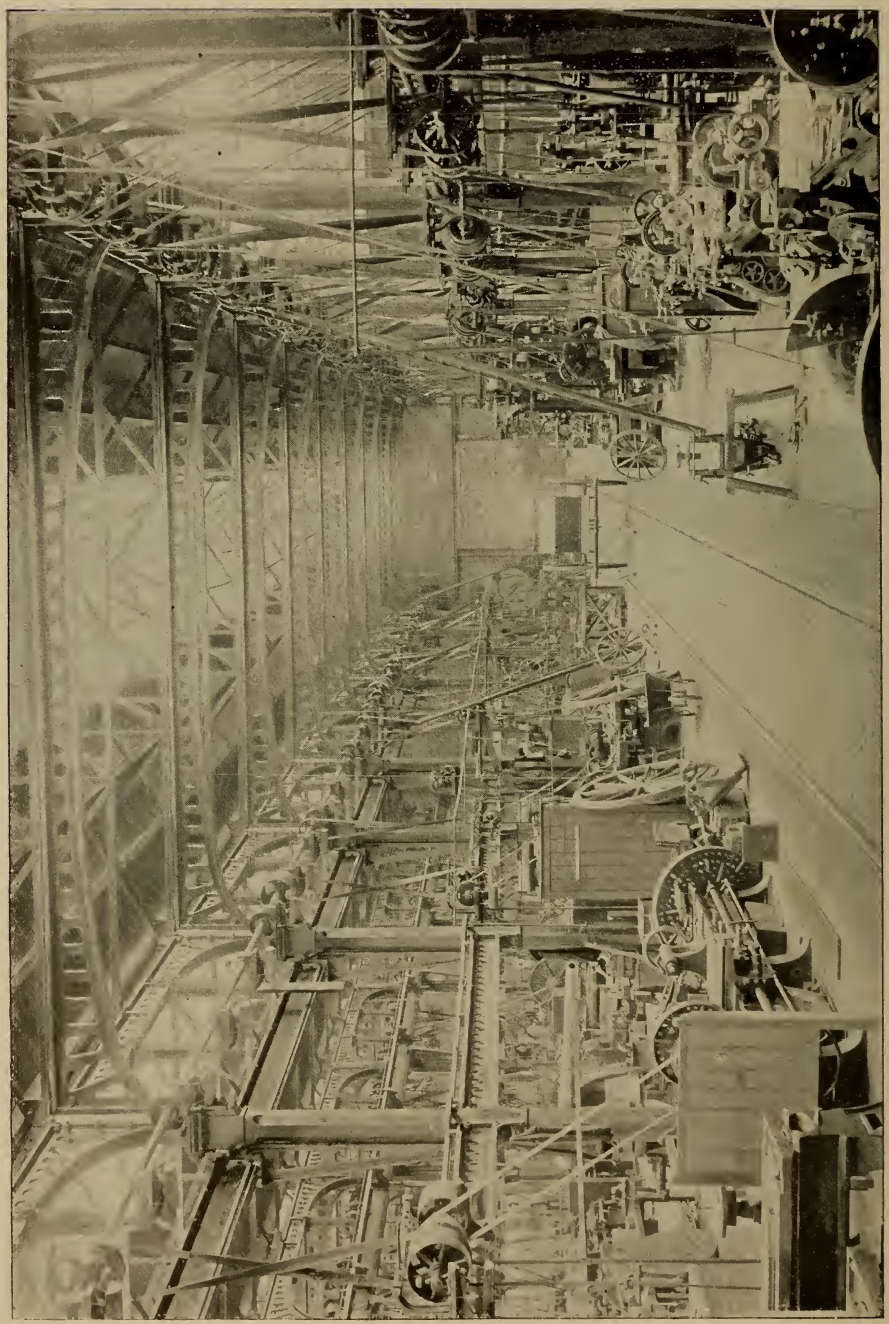
can be no question about it nor any as to the priority of my invention."

With reference to smokeless powder Mr. Maxim continued:—"As soon as I found out that such powder was being successfully employed on the Continent, I set about making some in England. Nobel had previously taken out patents for mixing nitro-glycerine and collodion cotton. He modified nitro-glycerine by mixing it with something which was less violent, but I was the first man to modify two violent explosives by compounding them together, *i. e.*, nitro-glycerine with gun-cotton, and I was the first man to use oil in this compound. I took out my patents in England and those to Professors Abel and Dewar were granted afterwards. I have been able, I believe, to obtain higher muzzle velocities with a lower pressure than any other experimenter. This is especially the case with quick-firing guns throwing projectiles of some 6 lbs. weight."

With reference to the production of smokeless gun powders, it is worthy of emphasis that Mr. Maxim was apparently the first person to advocate and explain in print the nature and uses of an admixture of nitro-glycerine and trinitro-cellulose for explosive purposes, or the use of an insoluble form of nitro-cellulose. This appears to have been a very important invention and disclosure when we regard the comparatively recent decision announced in the English courts with respect to the action



EXPERIMENTAL APPARATUS FOR ASCERTAINING THE POWER AND SPEED NECESSARY FOR FLIGHT.



PART OF THE MAXIM-NORDENFELDT GUN WORKS AT ERITH, ENGLAND.

brought by the Nobel Explosives Company against the authorities of the English War Office in connection with Professors Abel and Dewar's patents for "Cordite," granted in 1889.

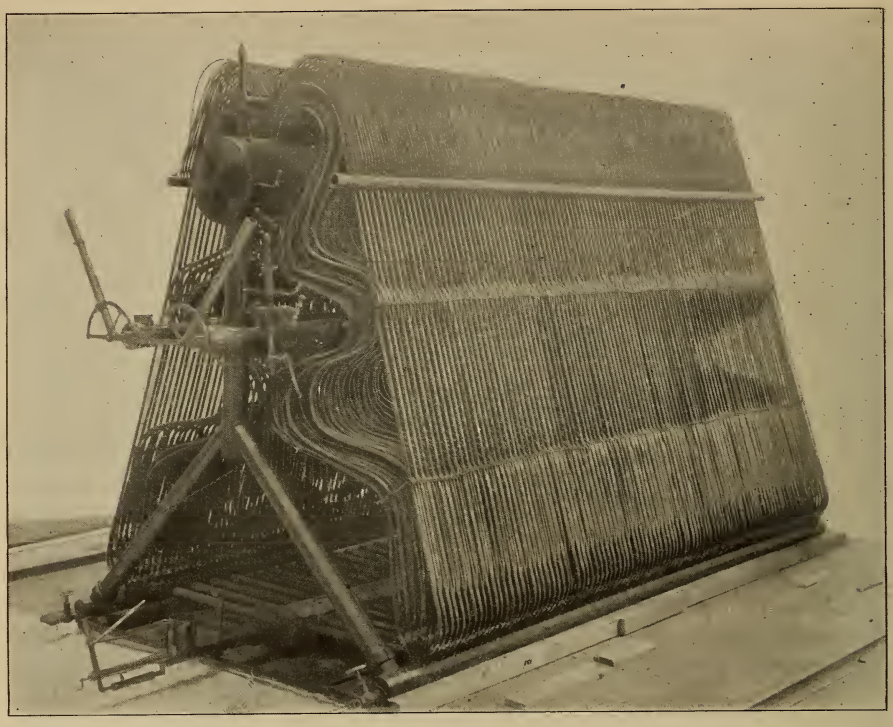
Mr. Maxim's British patent, describing the employment of insoluble cellulose, was filed in 1888, and in the year previous he obtained protection for a system of pressing such explosive ingredients through small holes or tubes so as to form them into homogeneous cords or filaments, a process very similar to that from which "Cordite" received its name. Therefore, prior to Abel and Dewar's patents in question, Maxim had, it seems, invented, patented and described—(1) a method of forming compounds of nitro-glycerine and nitro-cellulose into cord or wire-like shapes; (2) the substitution of trinitro-cellulose (insoluble) for di-nitro-cellulose (soluble) in connection with such explosive compounds, by the aid of acetone; (3) the addition of a suitable oil for toughening and reducing the violence of the product thus obtained. Those versed in matters pertaining to the manufacture of smokeless powders for propulsive purposes will readily appreciate the importance and value of his inventive attainments in this field of industry.

With the Maxim powder a muzzle velocity of about 2220 ft. per second, with a maximum pressure of only 10¼ tons per square inch, has been achieved in a three-pounder gun which uses a very heavy projectile in proportion to its diameter. It appears doubtful whether such a satisfactory result had ever been obtained before this experiment.

Apparently, the practical versatility of Mr. Maxim's inventive genius is almost boundless, for, in addition to his famous inventions for automatic machine guns, improved gun mountings, breech mechanisms, smokeless powders, and many others, we find him turning his energies in the direction of a revolutionary production of heavy ordnance. When the manufacture of steel was sufficiently advanced, it occurred to him that possibly it was then practical to construct artillery, of all moderate sizes, out of one solid steel forging, instead of building up the guns of numerous metallic coils or rings, as hitherto carried out. Should this course prove feasible in practice, it obviously meant a great economy in construction.

Accordingly, he erected a large and novel type of tempering plant at the Erith Gun Works for experimental purposes. Having obtained a large solid steel forging, a gun was roughly turned to size, bored, and then annealed, so as to remove all unequal molecular tension. The outside was then turned in the lathe again and the gun afterwards mounted vertically, breech down, in the tempering furnace, which is about 25 ft. high by 5 ft. diameter. Mechanism was provided for rotating the cannon whilst heat was being applied to it.

In order to prevent internal oxidation during this process, a current of coal gas was passed through the barrel. This not only effected the object in view, but it increased the hardness of the internal surface by the steel taking up some additional quantity of carbon. When the temperature of the rotating gun had been gradually raised to a bright red heat, the gas was shut off and a powerful stream of cold oil was substituted and forced through it. When this cooling process was sufficiently advanced, a stream of water was substituted for the oil, a very ingenious arrangement of pumping apparatus having been devised for this special purpose. After the furnace fire was exhausted and the gun rendered quite cold by the methods explained, it was removed and carefully examined. It was then found that the barrel was practically straight, whilst the internal surface was of increased hardness, and there was no distortion of any consequence. After the gun had been rifled and finished, it was taken to the trial ground, where it proved to be as good and strong as any artillery produced by the more expensive process of "building up." Increasing charges were fired in the gun, until the pressure exerted amounted to 22.5 tons per square inch, a test largely in excess of any practical requirements.



COMBINED BOILER AND FEED-WATER HEATER USING PETROLEUM FUEL, DESIGNED BY MR. MAXIM FOR USE ON HIS EXPERIMENTAL FLYING MACHINE.

Still, this enormous bursting pressure produced no baneful results. The gun showed no signs of yielding, and the calibre remained the same as before testing.

Exactments in respect to high-muzzle velocities were next tried, but the gun acquitted itself in a like satisfactory manner. The gun, which was a long 45-pounder, with a bore of 4.7 inches, fitted with a new breech action, was sold for a large sum immediately after its completion, and the Maxim-Nordenfelt Gun Company have since constructed several field and battery guns on this principle. They all have given satisfaction, and the inventor is of the opinion that guns up to fully 6-inch calibre can now be advantageously made out of one piece of metal.

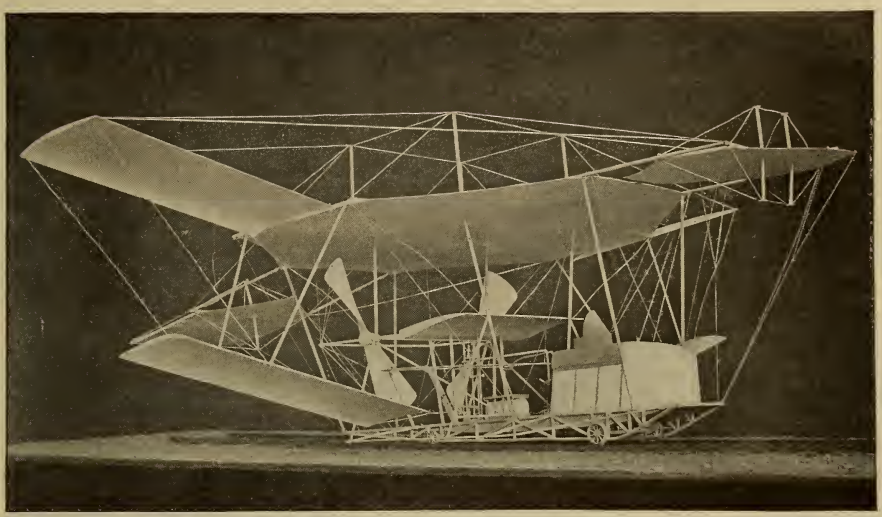
As is generally known, all heavy ordnance wears out very rapidly, owing to the eroding action of the gases of combustion upon the rifling of the barrels, and, indeed, the life of some big guns in the British Navy is said not to exceed 150 or 200 rounds of ammunition. The hot gases escaping around the projectiles after the discharge of the powder practically wear away the steel on the interior surfaces of the barrels. To overcome this defect Mr. Maxim has devised a projectile that effectually arrests the passage of gases; but it is possible that in this, as well as many other inventions, he is ahead of the times, for the prejudices and conservatism of gun manufacturers and military authorities are not to be set aside in a day.

Last spring, considerable interest was awakened in London by the announcement that Herr Dowe, of Berlin, would make his first appearance at the Alhambra Theatre on a stated evening with his famous "bullet-proof coat." A private exhibition was previously given, attended by many leading military and naval authorities. The writer

also was present. When, however, the Teutonic showman came upon the stage, it was soon apparent that the so-styled "coat" was really a breastplate, or cuirass, said to measure some 150 square inches in area, and weigh about 12 lbs. With its packing it looked about 2½ in. thick. The mysterious plastron, alleged to contain "no steel," was never allowed out of the performer's hands; neither was it ever measured or weighed before the public, but it certainly resisted the impact of regulation bullets fired from modern service rifles.

A stupid, but amusing, epidemic of excitement, or bullet-proof mania, soon seized the people, Mr. Maxim's attack taking the form of a jocular challenge to beat the German's exhibit with an "invention" which he had devised in a few hours and was willing to sell for 7s. 6d. His procedure was, doubtless, prompted by a laudable desire to expose that which he believed to be a "howling farce and piece of public deception," but many thought that the way in which he set about it was not altogether in good taste or dignified, and, indeed, it led to a good deal of misunderstanding, although Mr. Maxim's contentions were really sound enough.

On the 30th of May last he wrote to some London papers stating "that with a certain combination of organic and inorganic materials, he would," on a certain day, at the Erith Gun Works, "undertake to stop any bullets fired by service ammunition from English rifles," his "cuirass to measure 144 sq. in., and not to weigh more than 10 lbs." On the day appointed, a large, but mixed, assembly gathered at Erith from miles round, and amidst much enthusiasm Mr. Maxim's shield proved to be impenetrable and quite up to his promises. It was weighed and measured before the spectators, but Cordite or any other rifle ammunition did not pierce it.



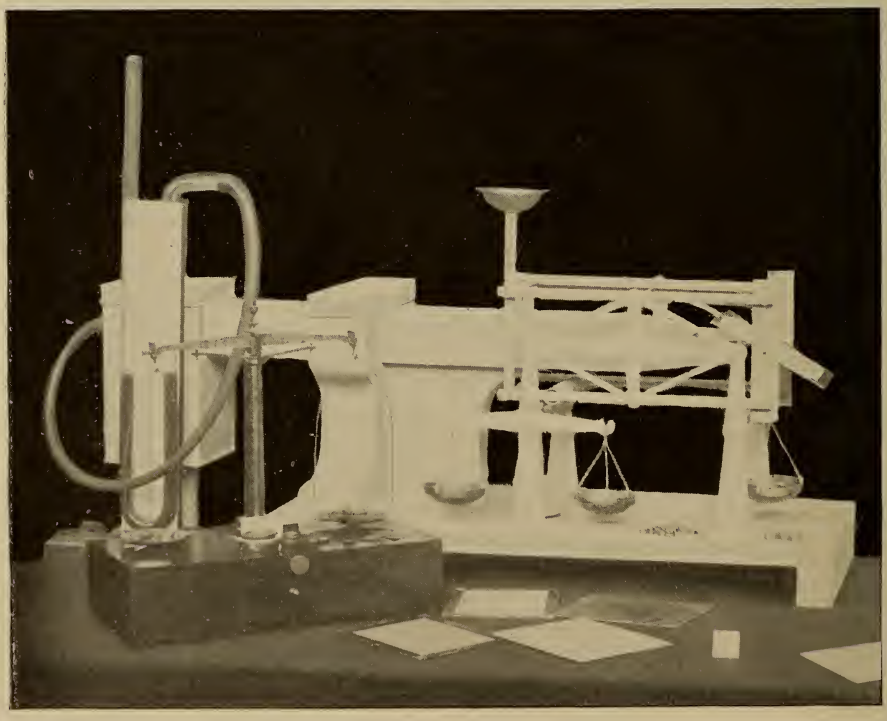
ANOTHER VIEW OF MAXIM'S EXPERIMENTAL FLYING MACHINE.

Later, however, when Mr. Maxim voluntarily explained to his audience that he had simply been employing a specially selected and treated piece of steel plate within a stuffed leather or cloth bag, many of his guests waxed exceedingly wroth and rent the air with their cries of indignation. So long as it was a secret it was all right, but now that he had disclosed his "invention," though it complied with all the conditions of

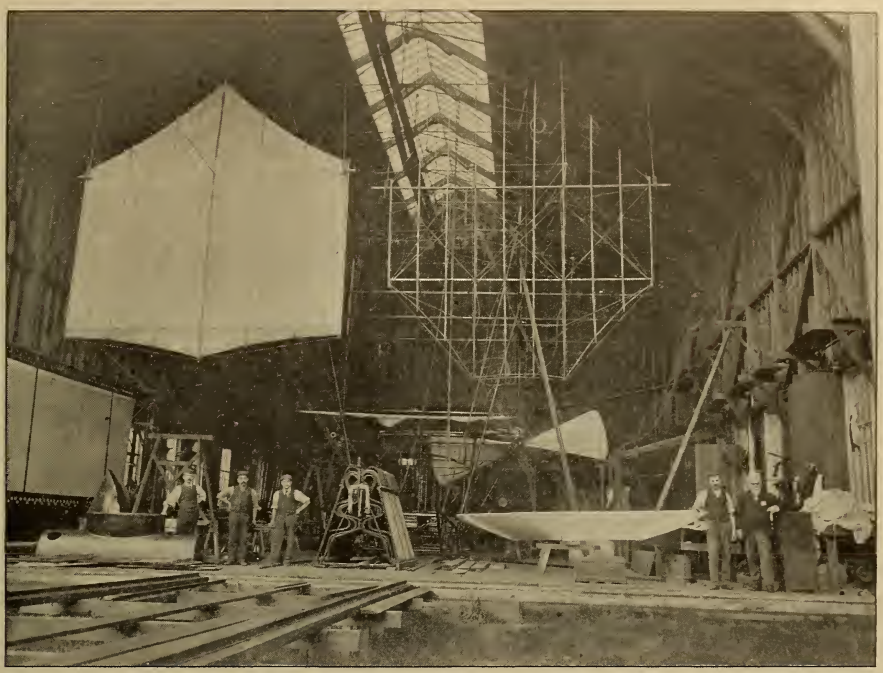
the Alhambra farce, it was called by some persons "an imposition," coupled with many other rude and unkind words. Mr. Maxim in vain shouted an explanation. The majority of the spectators' hearts were broken, the charm had been dispelled and their simplicity outraged. It was "Columbus and the egg trick" over again; they were inconsolable; it was so absurdly simple when they knew how it was done—most things are. They evidently expected to see him stop regulation bullets with his pocket handkerchief.

However, it was not so obvious as it at first appeared, for not one piece of steel in a hundred could have given such results, and, therefore, to those who understood this, the exhibition was pregnant with instruction. Nevertheless, most of the public went away disappointed. Mr. Maxim soon after proclaimed from the house tops challenges to Herr Dowe and the world at large, to come forward, and if they could beat his specially prepared steel plate for resisting bullets, the same weight and area considered, he would forfeit £100. Cuirass competitions were subsequently organized at the Westminster Aquarium amidst hideous noise and confusion, but the Maxim plate had come to stay, marksmen failing to get through it or inventors to excel it. Herr Dowe refused to engage in the trials and not even Mr. Maxim's hundred sovereigns would tempt him.

At length, however, a leading London paper offered to arbitrate between the hero of the plate and the Alhambra champion, the latter being simply asked to disprove the presence of steel in his cuirass; but all to no avail,—the German and his combination would not be "drawn" in any form. Then Professor Sylvanus Thompson kindly offered to ascertain



APPARATUS FOR TESTING MATERIALS USED IN THE CONSTRUCTION OF THE EXPERIMENTAL FLYING MACHINE.



PUTTING TOGETHER A FLYING MACHINE IN THE SHOPS.

by means of an electrostatic balance, whether iron or steel was present in the Alhambra exhibit, but a like refusal was proffered to him. Now the public began to think that there was humbug somewhere and that possibly, after all, Mr. Maxim was right. In the meantime bullet-proof cuirasses were being devised all over the country, whilst a dagger-proof coat made its appearance at the Crystal Palace.

Amidst this plethora of invulnerable arrivals, the Alhambra demonstrations were brought to a sudden termination and Herr Dowe disappeared; he had returned to his fatherland with the cash he had gained from a credulous and impetuous public. Then followed the sequel. The controversy was getting threadbare and speedily died a natural death when, some three months later, the *Reichsanzeiger*, of Berlin, announced that the so-termed "Dowe Cuirass," shown in London, was really a contrivance devised by a showman, Mr. Martin, who had put forward the German tailor for his own purposes. The paper then went on to state that "all the cuirasses have been pierced" and the Spandau Commission informed Dowe and Martin that "the device was of no practical value."

There was a strong confirmation of Mr. Maxim's views concerning the superior properties of special steel for resisting gunshots, which transpired in September last, when that eminent firm of steel makers, Messrs. Cammell & Company, of Sheffield, exhibited a really bullet-proof breastplate, composed of chrome steel. It weighed only six lbs., or half the alleged weight of the Martin-Dowe stage cuirass. This steel body covering was tested before the Duke of Cambridge and proved itself invulnerable to the attacks of Lee-Metford rifles with .303 ammunition, fired at short ranges, with a velocity of 2000 feet per second, and a striking blow of a foot ton, as close as 30 yards.

At the present time it might be thought, by some readers, remiss, or at least highly irregular, if this brief sketch of the great inventor's career were

MR. AND MRS. MAXIM AT THEIR HOME IN BALDWIN'S PARK, BEXLEY.

brought to a close without some reference to his celebrated experiments in connection with aeronautics. As so much has been recently published concerning them, however, but a little space will be occupied by such particulars.

Mr. Maxim began his aeronautic experiments in 1889, and although, up to the present time, their cost has been over £20,000, he was willing, after his ascent last year, to give the results of his labors to the public, so that, in the event of anything happening to him, others might profit by his experience and successfully pursue the study.

The intelligent world already knows that in July last his experimental flying machine succeeded in raising itself from the earth by its own contained power, and that this was the first instance in the history of the world where such a feat had been accomplished. This apparatus, as will be seen by reference to the illustration on page 451, was quite ship-like in its construction, being supplied with screws, weighing 135 lbs. each, and measuring 17 ft. 10in. over the tips of the blades. These screws were attached to a propeller shaft which ran at an average speed of 375 revolutions per minute. Besides the screws, as an assistance for keeping afloat, were great aeroplanes which, when all set, had an area of about four or five thousand square feet. The screws were operated by a pair of compound engines, supplied with steam from a combined multi-tubular boiler, feed-water heater and gas-heating burner, weighing 1000 pounds, provided with 7650 jets, the boiler having a heating surface of about 800 feet. Naphtha (72° Baumé) in the form of gas, at a pressure of

fifty pounds per square inch, was used for fuel.

The working pressure of the boiler ranges from about 275 to 320 lbs. per square inch, although the boiler has been tested at a steam pressure of 330 lbs. and a cold water pressure of 410 lbs. The motors, as previously mentioned, are compound engines, capable of jointly developing nearly 400 horse-power, and weigh but 600 lbs., or less than 2 lbs. per horse power. There are two high-pressure cylinders, five inches in diameter, and two low-pressure cylinders, eight inches in diameter. They are double-acting, have a common stroke of twelve inches, and a piston speed of 750 ft. per minute. These figures will give the reader an idea of the wonderfully light construction of the power plant, but it may be interesting to know that the entire machine, together with its full equipment of fuel, water and men, weighed less than 8000 lbs.

Before the machine was let loose from its moorings last July, a screw thrust of some 2000 lbs. was obtained, and it was demonstrated that the apparatus had a lifting capacity of over 10,000 lbs. while running at a rate of speed of forty

H. R. H. THE PRINCE OF WALES FIRING A MAXIM GUN.

miles an hour. The margin of power developed in favour of flight, as indicated by the recording apparatus on board, was fully equal to a net lift of one ton.

As a mechanical structure this machine is unquestionably a masterpiece of work, and it has been appropriately described by an eminent engineer as "not an invention, but a museum of inven-

A CORNER IN MAXIM'S STUDY.

tions." Professor Ball recently remarked that 1894 must "stand on record as the year in which the practical basis of mechanical flight has been accomplished," and such pre-eminent men of science as Lord Kelvin and Lord Rayleigh have personally extolled Mr. Maxim's attainments in this direction and have expressed the opinion that three out of the five problems involved have been definitely solved by Mr. Maxim. The two principal remaining points for him to demonstrate are the ability of his structure to maintain an "even keel," and reliable means of steering or manœuvring it when in mid-air.

Mr. Maxim's leisure time is still devoted to the development of his research, but as he is a very busy man this problem should, perhaps, be looked upon only as a hobby for his spare moments. The systematic manner in which he has proceeded with all his experiments, verifying every step, and taking nothing for granted, is worthy of the highest praise, and if nothing prevents the continuation of his labours in this direction the solution of the great question of aerial navigation should soon be solved. As to the future prospects of aerial flight, Mr. Maxim is of the opinion that "before the close of the present century we shall certainly see a practical flying machine, but it will be more serviceable for warfare than passenger or freight purposes."

The distinguished inventor has a fine residence at Baldwin's Park, Bexley, situated within a picturesque estate of some 500 acres in extent, and there he and his devoted wife spend most of their time in scientific study and deliberations. Indeed, the outside world has no idea of the inseparable nature of their lives, or of the invaluable services continually rendered Mr. Maxim by his zealous and intellectual spouse. Their virtues do not, however, end here, for their hospitality and geniality combined, have won them the highest esteem of a wide circle of friends and acquaintances.

MAXIM IN HIS LABORATORY.

WHAT ELECTROLYSIS WILL DO WITH WATER AND GAS PIPES.

# THE LEGAL ASPECTS OF ELECTROLYSIS.

*By Henry C. Townsend.*

IT is, at the present time, a well-settled fact that a continuing and serious damage is done to buried gas and water pipes and to the metal sheaths of buried telephone and other cables by the action of electricity as now generally employed by electric railway companies for propelling their cars, and, while efforts are being made to obviate the trouble, the success of the remedies proposed or their suitability for constantly changing conditions is somewhat doubtful so long as the rails are employed as a part of the electric return circuit.

It is generally admitted that a complete remedy is found in the use of a return circuit entirely insulated from the earth, such as would be afforded by the use of a double trolley wire ; but there is a natural aversion on the part of the street railway companies to such an expedient because of its expense, although it may be seriously questioned whether the deterioration or corrosion of the rails themselves, when buried in the earth and used as a return circuit, is not a source of loss whose magnitude, if fully appreciated, would virtually compel the adoption of this remedy.

The disposition, however, is to palliate the evil, if possible, by improving the conductivity at the rail joints, thereby furnishing so good a path for the return current that the amount diverted to the earth and to buried conductors will not produce a material injury. The injury arising from imperfect bonding had,

HENRY C. TOWNSEND graduated at Harvard College in 1871, shortly after entered the United States Patent Office and was examiner in the class of electricity from 1873 until 1880. In 1873 he was admitted to the bar of the Supreme Court of the District of Columbia, and in 1880 to the bar of the Supreme Court of the State of New York and the United States Circuit Court. Since then he has been employed in many important patent litigations for the leading American telephone, telegraph and electric light companies, where special and extended knowledge of the state of the art in electricity has been important. While connected with the Patent Office, Mr. Townsend passed upon many of the leading inventions which have been responsible for the present era of activity in electrical matters. Electrolysis and its destructive effects have formed one of the subjects to which Mr Townsend has given much attention and his expressed views of it will be found to be decidedly instructive reading.

however, grown to be very great before the extent of the evil had been suspected, and will continue to exist wherever the bonding is imperfectly done or where it may deteriorate.

The question arises on this general state of facts,—Upon whom does the responsibility rest for the injuries heretofore accruing, or which may hereafter arise, from the corrosive action of the railway currents? A similar question arose some years ago in controversies between the telephone and electric railway companies. The injury complained of by the telephone companies in these cases was due, not to corrosive action of the railway currents, but to the inductive disturbances upon their pole-lines parallel to the trolley wires, and to the presence upon the telephone lines of the electric railway currents passing to earth and thence to such lines.

In the majority of these controversies the courts refused relief to the telephone companies, and it has been suggested that these cases furnish precedents for the disposition of such controversies as may arise from the corrosive action of the railway currents upon buried metal. Their value as precedents is, however, open to grave doubt.

The contention of the railway companies, as advanced in the prior cases, virtually resolved itself into the claim that they cannot be held liable for the injuries caused to neighboring property through the operation of their road by electricity, because their enjoyment of their rights and franchises is in pursuance of legislative authority. But, as said by the Supreme Court of the United States in a similar case, the grant of powers and privileges to do certain things does not carry with it immunity for private injuries which may result directly from the exercise of those powers and privileges, nor is the liability of a company to respond for damages caused by it affected by its corporate character. Its liability for annoyance, discomfort or damage is the same as that of individuals for a similar wrong.

Nor is its liability affected by the extent or character of its franchise. Whatever the extent of the authority conferred, it is accompanied with the implied qualification that it shall be so exercised as not to work an annoyance or damage to others, and, even if that authority extend expressly to permitting the use of the rail return, the liability for damage caused thereby cannot be escaped, although in some quarters the notion prevails that the railway company cannot be held liable, on the general rule that whatever is authorized by competent authority cannot be treated as a nuisance.

There is, however, a wide distinction between that class of cases in which the act complained of is a public work, done under the authority of the government by persons deriving no personal advantage, but acting within the best of their skill and scope of their authority, and that in which the act, complained of as having wrought injurious consequences, is done by private individuals and not essentially for a public purpose, but for private emolument. In the one case the execution of the act is a public duty imposed by the government, and which, having been accepted, must be executed; no claim can lie for consequential damages arising from the execution of that duty. The act of the other is not essentially and only for a public purpose, but mainly for private emolument.

The electric railway company, in respect to individuals or the public, stands in the position of doing an act for its own profit and benefit, the direct and necessary consequence of which is an injury, if the act from which that injury arises is the use or operation of its system by a return through the rails. The act upon which the legal injury is founded is not the operation of the road by electricity generally, but the employment of the specific kind of plant which the company has elected to build and operate, not because the purposes of its character, so far as the benefit of the public is concerned, could be best carried out by that plan of operation in preference to the system which would work no injury, but because it is primarily for its own pecuniary benefit,

though attended by a continuing and grave pecuniary damage to the physical property of others.

It cannot be justly claimed that the beneficial uses of the street, so far as the public is concerned and in respect to the uses for which the railway company becomes the servant of the public, are in any substantial manner enhanced by the employment of the earth or rail return circuit in preference to that other method which was open to the railway company to employ, though at considerably greater expense and, of necessity therefore, at a diminution of profits. Facility and speed of transportation in the city streets is the primary purpose or benefit in consideration of which railway companies enjoy their franchises to employ the electric current, but no one can safely affirm that this benefit can be accomplished only by the use of that one of the known systems of distributing the electric power which is now generally employed.

The question is, practically, whether the railway company, for its own profit, and not for the benefit of the public interest in the streets, shall be allowed to employ that method of distributing its power, of which the usual and known consequences are to work a serious interruption to the enjoyment of a previously granted franchise in pursuance of which the streets and the earth have been occupied for the operation of a plant in what was, at the time of its installation, a well-known and recognized way and was within the corporate powers and grants. There are wrongs, or damage, for which the law provides no remedy, and it is the general rule that if the owner of property, in the prudent and necessary exercise of his own right of dominion, does acts which cause loss to another, it is, as the law puts it, *damnum absque injuria*. So, too, acts of public agents, within the scope of their authority, if they cause damage, cause simply *damnum absque injuria*.

With some exceptions the general rule is said to be that no person is liable for damages incidentally occasioned to others by the necessary and beneficial use of his own property or of a franchise granted to him by the State ; that every man has the right to the natural use and enjoyment of his own property, and if, while lawfully in such use and enjoyment, without negligence or malice on his part, an unavoidable loss occurs to his neighbor, it is *damnum absque injuria*.

On these general propositions a Circuit Court of the United States denied relief to a telephone company, injured by the operation of an electric railway with a ground return ; but the decision seems to have rested largely upon the erroneous assumption that the use of the ground return was necessary to the enjoyment of the franchise of electrically propelling cars. Even if, however, the use of the single trolley be lawful, the charge of negligence cannot be escaped if the railway company fail to use the best method of bonding its rails, provided that bonding would remove the damage from corrosion, and any damage that could be shown to have resulted from its failure to use the best means in its power would be recoverable.

While the failure to use the double trolley may not, in the opinion of the courts, constitute a reasonable ground for charging negligence in those cases where a telephone company is injured by induction or vagrant currents passing onto its lines and ringing its bells, such a ruling affords no precedent under which the railway company may be held to be relieved of the obligation to use the best rail-return after it has elected to adopt that method of enjoying its franchise. But not a few cases are found in the reports wherein a company is held liable for damages caused by acts done within its chartered powers.

A notable one, peculiarly apposite to the matter here treated, is that of a corporation charged with repairing the public streets, and which, in so doing, used rollers so heavy as to injure buried gas pipes. The rollers were economical and well fitted for the purpose, but the repairs could have been effected by rolls which would not have produced

the injury. The defendant was held liable for the injury. Here was a case of a public grant to a gas company, enjoyed in a certain way, followed by the grant to another company to exercise a right which, if exercised in one way, would injure the former, but, exercised in another, would not.

In another case the defendant was a corporation engaged in digging a canal. In the prosecution of the work it was found necessary to blast rocks, and the fragments injured adjoining property. For this immediate and direct damage, resulting from an authorized act necessary to the enjoyment of the privilege, the company was held liable.

In still another case a company, under authority of the government to enter a city with its tracks and to construct such works as it might deem expedient for the completion and maintenance of its road, placed its engine repair shops in a position where they interfered with the use of neighboring property, acquired by the plaintiff long before the shop was built. The Court held that such authority did not permit it to place its shops wherever it might think proper without reference to the rights of others. The Court said :

"Whatever the extent of the authority conferred, it was accompanied by the implied qualification that the works should not be so placed as, by their use, to unreasonably interfere with and disturb the peaceful and comfortable enjoyment of others in their property. Grants of privileges or powers to corporate bodies, like those in question, confer no license to use them in disregard of the private rights of others and with immunity for their invasion."

As to the running of the cars in the streets, it held that no one could complain of the incidental inconvenience unavoidably following the occupation of the streets by the cars and the noises attending the running of them. The damages by electrolysis cannot, however, be said to be unavoidable, because there is a plain remedy in the use of the double trolley, the employment of which is not inconsistent with the full enjoyment of all the advantages to the public from electric transportation. Among other instances are the flooding of another's land by a party authorized to build a dam. The authority was held not to carry with it immunity for the resulting damage. So, also, the diversion of the waters of a running stream by the trustees of a city, authorized by statute to provide a water supply for a city, was held actionable.

In another case a railway was adjudged not liable to a telephone company on the ground that the dominant purpose of the streets is public travel and transportation, and the right of the railway company to use improved modes of conveyance was, therefore, superior to the rights of the telephone company. Whether or not this decision be sound, it is obvious that it affords no support for the proposition that the railway company is not responsible for material and direct damage to gas and water pipes.

While the chief use of the streets is for travel, this is not the only use recognized by the law. The laying of water and gas pipe has long been recognized as a necessary use and may be well held superior in importance to that use which involves the employment of electricity in the particular way which works a damage to the property of others while another way, free from objection, is open to adoption. Claims to immunity for damage, because of superior right, will not, we imagine, avail the railway as defences in any suit brought for a damage that could be proved to result to water or gas pipes from the grounded electric railway return.

In the telephone cases the courts were apparently influenced to a decision in favour of the railway company by the consideration that the injury to the telephone company was in the nature of an inconvenience rather than a direct or material damage—the visible, positive and necessary result of the railway current. The opinion seems to have been that as there was no actual, physical invasion or destruction of property, amounting to a taking, or visible damage, capable of exact ascertainment,

therefore, the injury should be treated as consequential and not to be remedied in the absence of fault or negligence in the exercise of the railway franchise. Nevertheless, it is well recognized that a serious interruption to the common and necessary use of property may be equivalent to a taking of it, and so be within the prohibition found in the constitution of most of the States in America that private property shall not be taken for public use without just compensation, and it is not to be supposed that the courts intended to go so far as to ignore that principle, founded on the natural principles of equity.

The damage to water and gas pipes is a continuing and material one, involving a physical destruction of property and practically an invasion of it by a foreign agent or force, called into action and directed to the pipes by the acts of the railway company, and which, like other natural agents, as water, light, heat, is, as Blackstone puts it in the case of water, a "wandering thing," only kept in bounds and directed by some positive means applied by the user.

In prior adjudications upon the rights of telephone, telegraph and electric light companies, as joint occupants of the public streets, courts have apparently found difficulty in dealing with the subject, because, in the strictest sense, there is no physical invasion of property such as exists in the case of the flooding of lands or a trespass on property. Modern research, it is true, indicates that light and electricity are but different manifestations of properties of the same medium, filling all space and termed ether, and modern theory goes so far as to assert that such apparently diverse forces as electricity, light and gravitation are properties of this one universal and all-pervading ether. A recent Secretary of the Treasury of the United States has ruled that electricity, conveyed by conductors laid across the frontier, is not dutiable, being, as the learned Secretary put it, "intangible and not capable of being measured," and a State court has exempted an electric light company from taxation as a manufacturing corporation on the ground that electricity is not a manufactured article.

Nevertheless, although electricity is not a substance or fluid in the ordinary sense, the idea of fluid pervades the whole language of electrical science and even the definition of electrical units, as adopted by all scientists, suggests a fluid theory, and so the analogy of water naturally suggests itself in dealing with the present subject. So dealt with, the law furnishes many analogies in its treatment of the rights of riparian owners and of persons injured by water, heat or other natural agent. Many of these analogies support the proposition that the invasion of a telephone company's plant by foreign and superior currents, if producing a serious interruption of, or interference with, its use, is a damage for which the law gives a remedy, but the analogy approaches much nearer to exactness in the cases where the injury goes beyond the mere annoyance or temporary interruption to use, such as was considered to exist in the case of the telephone companies, and involves the actual physical destruction of the property invaded, as is the case of corroded water and gas pipes or telephone cable sheaths. These injuries cannot be dismissed as mere incidental inconveniences, unavoidably following the use of electricity for street car propulsion. The damage is a continuing, physical one, and is repeated with every repair. It is, moreover, the natural proximate and immediate result of the use of the ground return, chosen by the companies in preference to the double trolley, mainly for their own convenience and profit rather than for giving increased speed of transportation.

It has been urged, as in the telephone cases, that the demand for damages or injunction by those whose previously acquired property, or rights of property, are injured by the railway currents introduced into the earth, amounts to a claim to the monopoly of the use of the earth. But priority of enjoyment of a right is frequently a factor in determining what is or is not a nuisance. Thus,

it was held to be a nuisance in a certain case for the defendant, a pastry cook, to put into a room in his house which adjoined a room of the plaintiff, previously long used as a wine cellar, a stove so large that, when it was being used, it heated the wine cellar and made it useless for its purpose.

Blackstone says of nuisances: "If one does an act in itself lawful, which, yet being done in that place, necessarily tends to the damage of another's property, it is a nuisance, for it is incumbent on the person to find some other place to do that act where it will be less offensive." And it is a general rule that acts, lawful in themselves, may become unlawful if exercised without regard to time, place and circumstances. An offensive trade may not be established on one's land to the prejudice of the previous occupants of neighboring land; but if the neighboring land be not occupied there is no nuisance.

In the previously mentioned case of the railway repair shops, established on land owned by the company, to the interference with the enjoyment of neighboring property, one of the grounds upon which the court granted relief was that the property had been acquired and put to the special use which was interfered with, long before the railroad shop was built.

A distinction exists between such injuries as may result from the uses of the public streets by different persons, owing to a conflict of their interests and methods of use, and such injuries as may result to the rights of the owners of abutting property, due to corporate or other acts in a street or highway. As between two occupants of the public highway, each exercising its right by legislative authority through the power of control which the State has over the streets for public uses, the State may, in the exercise of its power of eminent domain, authorize a beneficial use in a manner to work an injury to another use beneficial to the public, if public necessity or convenience may require it. But this is subject to the constitutional right of the person injured to just compensation if the injury amount to a taking or damage, or amount to more than a mere incidental injury or inconvenience. But, in respect to abutting property there resides in each owner an easement or right to the unrestricted use and enjoyment of the street for purposes of access for drainage, supply of heat, light, water, etc., which the law recgnizes as appurtenant to the land and not passing with any conveyance of the street or land therof to the State or corporation for street uses.

Each lot owner has a peculiar interest in the street which neither the State nor the municipal corporation, nor the general public can pretend to claim—a private right of the nature of an incorporeal hereditament legally attaching to his continuous grounds and the erections thereon; an incidental title to certain facilities and franchises. This easement, appendant to a lot, is as much property as the lot itself. For an injury to that right the law gives the land owner a remedy by injunction or award of damages, according to the nature and the circumstances of the injury.

While the electric railways may lawfully occupy the streets for the purpose of facilitating the uses of the streets for passage and transportation, they cannot impair or lessen lawfully an abutting owner's easement in it by any method of operation which attaches to the maintenance and use of the electric railway in any special or particular manner. As was held in the elevated railway cases in New York, the use of the streets by the railway structure operates to take from the abutting lot owner a portion of his easement in the street, without making compensation, and, hence, as to him, it is illegally there, although, so far as concerns the public, the rights of the road could be allowed to stand. The illegality in respect to the lot owner was not in making use of the franchise legally granted, but in appropriating a part of the owner's easement without acquiring it by negotiation or condemnation.

In this particular case the easements taken were those of light and air, impaired by the presence of the structure and by smoke, cinders, gases, etc., which

were necessary accompaniments of the operation of the road. But there are other easements which undoubtedly belong to the abutting lot owners, namely, the right of gas and water connections ; and, if these be impaired by the use and operation of the electric railway, there is an injury or damage for which the owners are entitled to compensation.

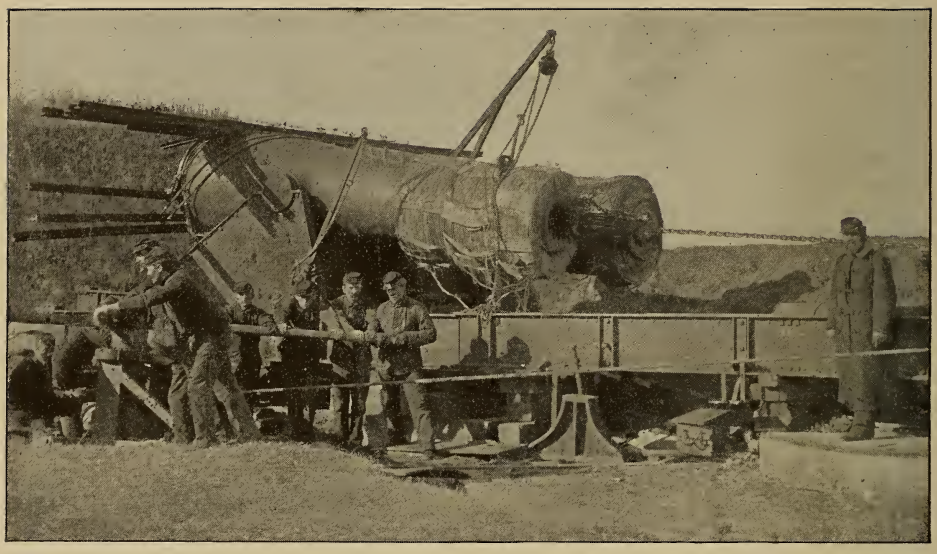
The appropriation of the land forming the street for street uses carries, by implication, the extension of those in vogue at the time of the grant, dedication or conversion, to those which the progress of civilization and the growing demands of increasing population may require ; therefore, a use of the streets for cars or vehicles propelled by electricity, in so far as increased rapidity of movement may be beneficial, is within the purposes of the original use. But this principle cannot be equitably extended so as to legalize particular ways of employing the electric force which are inconsistent with, and subversive of, those prior, necessary uses of the soil of the street for carrying water and gas pipes, or of the right of the abutting owner to make connection with them.

While, therefore, the courts may dismiss the claim of a telephone company fordamages arising from joint occupancy of the streets because the injury is the result of a joint attempt of individuals to make use of that to which each alike has a right, and is produced without fault or negligence on the part of the railway company, no such disposition would necessarily follow as to any claim which the owner of an abutting lot might make for damage to his easement in the street for the purposes of water and gas pipe connection, because, on principle, that use stands practically upon the same footing as his right to secure light and air from the street.

A remedy exists for the injury by corrosion to which buried pipes and cables are at present exposed through the operation of the electric railway companies, and while the difficulty is, from the electrician's standpoint, best met by resort to the double trolley, there is sufficiently reasonable expectation of relief from the expedients which are now being proposed to free the railway companies from the charge of negligence.

The remedies now proposed will in any case probably so diminish the evil that it will become difficult to place the liability, or to say with certainty that the extent of corrosion to be hereafter observed is not attributable rather to the direct corroding influence of the constituents of the earth itself or to the decomposing action of the weak currents which may be set up, as in an earth battery, by different sections of pipe or cable, electro-positive and negative to one another either by reason of the difference of the metals themselves, or by different kinds of earth in which neighboring, similar metals are buried.

It is beyond the compass of this paper to discuss the different ways in which feeble earth currents may be set up, but inasmuch as recent experiments seem to show that a mere directive force in the way of electric pressure, even so low as 0.001 of a volt, is sufficient to produce electrolysis of the earth salts and liberate corroding agents, it is quite obvious that without resorting to the double trolley the corrosion may be so far diminished by other proposed means that the responsibility for the corrosion remaining cannot be fixed upon the railway companies.

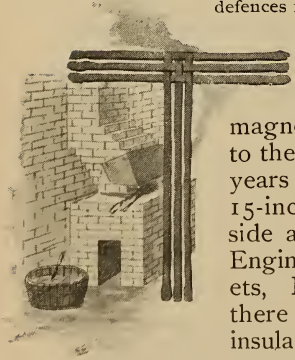


THE LARGE DOUBLE-GUN MAGNET AT WILLETS POINT, N. Y.

# LARGE GUNS AS MAGNETS.

*By Lieut.-Col. William R. King, U. S. Engineer Corps.*

Lieut -Col. William R. King, United States Engineers, was graduated at the Government military school at West Point, and commissioned in the Corps of Engineers in 1863. He is now commandant at the U. S Engineer School at Willets Point, N. Y., and is in charge of engineering work on the military defences for the eastern entrance to New York Harbor.



THE idea of constructing a huge "gun magnet" was suggested to the writer some twenty years ago by seeing two 15-inch guns lying side by side at the United States Engineer School, at Willets, New York, but as there was then no suitable insulated wire at hand and as no means were available for generating a powerful electric current, nothing was attempted at that time. In 1888, however, the accumulation of several miles of condemned torpedo cable and the presence of some large dynamos brought the subject forward in a still more suggestive and practicable form, and the experiment was tried.

The guns, weighing 50,000 lbs. each, were placed side by side and connected at the breech by a pile of railway bars. Coils of insulated wire, some eight miles in all, were placed around the muzzles of the guns, and an armature, 7½ x 11½ inches in cross section, was made of wrought iron plates bolted together.

This arrangement is shown in the illustration on the next page, which will need no further explanation.

When the current was turned on it was not only found that a magnetic field of unprecedented intensity was formed, but an exceptional opportunity was presented for studying the phenomena of electro-magnetism. The lines of force could be traced to a great distance, and they were mapped out on a large drawing board, as represented in the diagram on page 466. A pull of 20,600 lbs. was required to detach the armature, and four 320-lb. projectiles were suspended like a string of beads from one of the guns.

In more recent experiments with a single gun, wrapped with about ten miles of wire, and having the magnetic circuit completed by a pile of heavy iron plates, the pull required to detach the armature was 44,800 lbs., and five of the projectiles were supported from the muzzle. It is, perhaps, needless to say that the extravagant statements recently circulated about this magnet are without foundation. It was never intended "to derange ships' compasses" at *any* distance, and it certainly could not do so at a range of "six miles," nor could it pull vessels out of the water or arms out of the hands of soldiers. Such statements would refute themselves if it were not for the fact that electricity has, for several years past, been doing such unexpected things that even scientific men hardly dare to say that anything claimed for it is impossible.

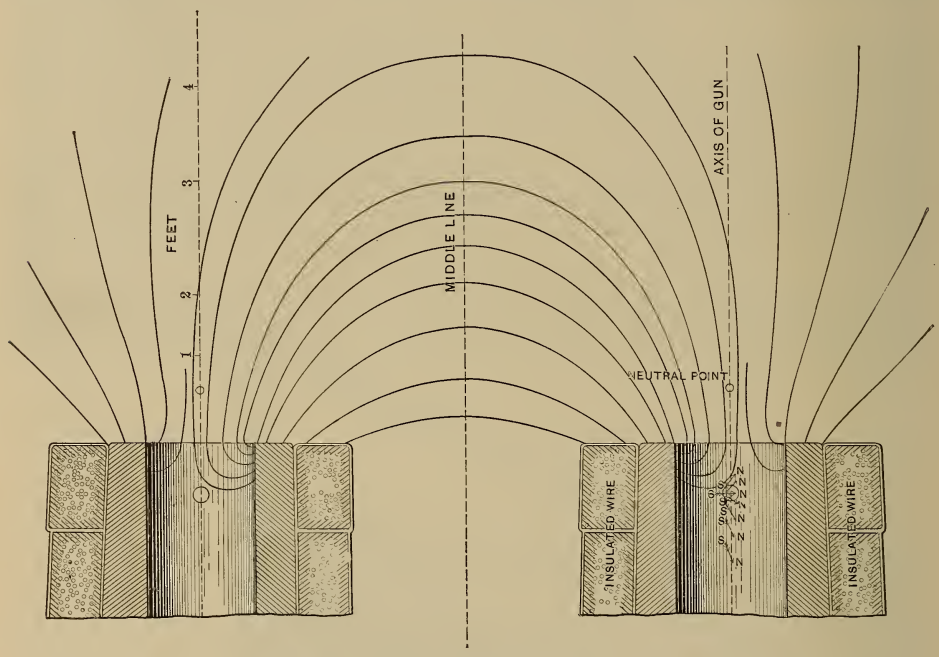
In this utilitarian age the first question asked is, "What is a thing good for," and, in this case, the answer is, "To

A LATER, SINGLE-GUN MAGNET, SUPPORTING 44,800 LBS.

study electro-magnetism on a much larger scale than has hitherto been attempted." It is well known that all physical laws can be better understood by studying extreme cases as well as intermediate ones, and in this instance several results have been observed that have escaped notice in ordinary experiments. It is not proposed to enter into the details of these experiments at this time, as they have not been entirely completed, but a few of the results may be of interest.

effect can be detected on the nerves or muscles of the human system, although the lines of force sent through the head or heart are strong enough to cause iron bars, spikes, etc., to stand out like the quills of a porcupine, as shown very strikingly in the illustration on the next page.

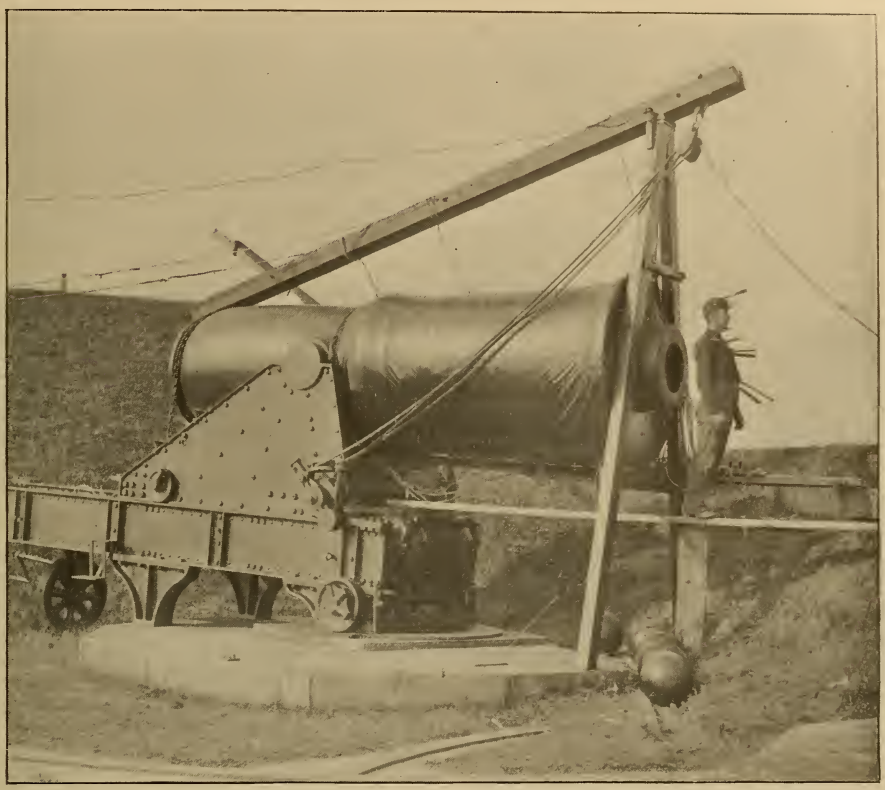
Theoretically, such a strong magnetic field should check or "damp" the vibrations of metallic strings, but in the few experiments tried no such effect was perceptible. Three strings of a sonom-




LINES OF FORCE IN PLANE OF AXES OF GUNS.

At a distance of about seventy-one feet the field of this magnet is equal to the earth's field, or in other words it will deflect the needle 45 deg. at that distance. At a distance of 200 feet the deflection is 3 deg. At about 7½ inches from the muzzle of the gun there is a neutral point at which a small piece of iron is neither attracted nor repelled. If placed nearer the gun, but in its axis, it will be thrown out with some little force, sometimes as much as two feet, and then drawn back obliquely to the side of the muzzle. No perceptible

eter, one each of iron, brass and twine, were all tuned to "b flat," but when sounded together in the magnetic field, close to the muzzle of the gun, they were still in unison as nearly as could be detected. Neither was there any perceptible effect on light. For the purpose of testing this a transit was set about 30 feet from the magnet and sighted, at a well defined mark several hundred feet beyond it, the line of sight passing only a few inches from the magnet. When the current was turned on no change what-



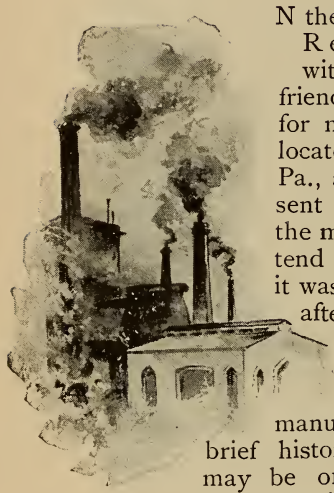
EFFECT OF THE LINES OF FORCE THROUGH A HUMAN BODY.

ever was observable in the appearance of the object. In other words, the rays of light were not bent.

These last three results are of a negative character, but they are conclusive as far as they go. In these experiments there were about 5250 turns of wire around the gun, which, with a current of about 21 amperes, gave over 110,000 "ampere turns." The cross section of the cast iron core varied from 300 square inches at the muzzle to about 1500 square inches at the largest place. The length of the gun is about 16 feet, and the coils of wire cover about one-half the length.

# THE FIRST THREE-HIGH ROLL TRAIN.

*By John Fritz.*



IN the year 1854, David Reeves, together with a few of his friends, leased a works for making iron rails, located at Johnstown, Pa., and the writer was sent there to complete the mill and to superintend its working. As it was at this place that afterwards great and important changes were introduced in the manufacture of rails, a brief history of the works may be of interest. This was first given by the writer in the course of a presidential address recently delivered before the American Institute of Mining Engineers, but it may be of interest to others, and to iron workers especially.

The works were originally commenced by an organization called the Cambria Iron Company, but after the mill was partially built, their money gave out, and the project was considered a failure. It was at this time that David Reeves, Mathew Newkirk, George Trotter and a few others, joined together and leased the plant as it stood; Mr. Reeves, Mr. Trotter and Mr. Newkirk being the most prominent in the matter, and Mr. Newkirk acting as the business manager.

Mr. Newkirk then gave me instructions to go to work at once and complete the mill as soon as possible. Having previously examined the works with great care, it was with serious misgivings that I undertook the task. There was a vast amount of new work to be supplied, and I had very serious doubts as to the efficiency of what had previously been done. From what I learned as to the kind of pig-iron that was to be used, the outlook was anything but encouraging, and I came to the conclusion that there was serious trouble in store for me when the mill would be ready to start; and I can now testify that my forebodings were fully verified later on.

When we at last got to work and rolled a few rails, the edges of their flanges looked like saw-teeth, and the head was rough and full of small holes, and everybody about the mill, from the owners to the water-boy, was disgusted and sick. This was especially true concerning the heaters and the men about the rolls, for they were paid by the ton of finished rails. It was the general conclusion that something would have to be done, and right quickly, too. There were three charcoal blast-furnaces that belonged to the company, one of which happened to be in blast at the

Few men, probably, have been more closely identified with the history of iron and steel manufacture in the United States than JOHN FRITZ. Beginning at a very early age as an apprentice boy in a country machine shop, he worked his way successively through all stages to one of the highest points of honor and appreciation which an engineer may hope to attain, retiring from active professional work a little more than a year ago. He is one of a group of eight or ten persons who might well have been designated as the "Bessemer boys" of '65 and '70, and who pushed forward inventions, plans and appliances which, though seemingly hazardous, happily, in most instances, proved successful and which did much to advance with rapid strides the production of both iron and steel in the United States. Not the least important of Mr. Fritz's many engineering achievements was the building of the first three-high roll train in the world, some of the incidents of which he tells of in this article.

time, so we got some charcoal-pig and puddled it and rolled it into covers for the bottoms of the rails, the common iron being above them. These piles were rolled so as to put the charcoal-iron on the edges of the flanges. This worked pretty well as far as the flanges went, but it did not cure the trouble with the heads ; so we had to roll other covers for the tops of the piles, to make the head of the rail good ; and with hot and cold patching, and a liberal use of putty, we managed to get some rails that passed muster. By continually experimenting in the piling of the iron, and changing mixtures, we finally got out some fairly good rails ; but the engine and fly-wheel driving the train were of such a construction that it was not safe to run at over fifty revolutions per minute, which was too slow to make rails out of the materials we were using.

One of the most serious troubles was, that the forward end of the pile would split open in the rolls, so that, when we came to enter it in the next pass, it refused to go in, and much time was lost in bunting it in the buggy, consequently cooling the pile to such an extent that, when the rolls did get hold of it, spindles, coupling-boxes, and sometimes the rolls themselves, would break, causing both expense and delay, which, in connection with the general depression in business, led to troubles that brought the enterprise to an end.

Again a new company was formed, and it was known as Wood, Morrell & Co. It was in part made up by David Reeves, Charles Wood, Mathew Newkirk, George Trotter, D. J. Morrell, John Shoenberger and E. Y. Townsend. Mr. Charles Wood was made president, E. Y. Townsend, vice-president, and D. J. Morrell, general manager. The change in the organization of the company did not, however, change the troubles in the manufacture of the rails, nor increase the output,—both exceedingly important matters, which, unless they could be greatly improved, would still leave the handwriting of failure on the wall. Having, in view of the past, and remembering my former doubts, gone over the entire subject again, I made up my mind as to what must be done to make a success, and I was prepared to submit my plans and recommendations to the new company.

My plan was to build an entirely new train of rolls and to make them three-high and 20 inches in diameter. This involved a new engine with a fly-wheel that could be run at one hundred revolutions, should it be desirable to do so. In fact, it practically meant an entirely new rail-mill. When the plan was submitted to the company, they said at once it could not be done, for the reason that the expense would be too great ; and besides, the mill they had was an entirely new mill, which was supposed to be the very best in the country, and they did not see why it could not be made to do good work. Finally, I succeeded in convincing some of the managers that something must be done, and that if they would adopt my recommendations I was certain of success.

After consulting together, they directed me to go on and build an 18-inch two-high geared train to take the place of the train we had. To this I replied in the most emphatic manner that I would not do it, as it would be money thrown away. To my refusal, they said the position taken was a most arbitrary one, and one I had no right to take, as I was in their employ on a salary to manage their works, and that they had some right to say what should be done. To this I assented partially, but at the same time told them, that if they continued in the line they were in, there would in a short time be held a large funeral, and I did not intend to stay and attend it. At this the meeting adjourned.

In a few days they gave me permission to go on and build such a mill as I wanted, but they thought it would be better to make the rolls 18 inches instead of 20 inches in diameter ; and, by way of compromise, I consented (which was a mistake), and began to build the new train and make other important changes about the mill.

About the time we had the patterns for the new train and engine completed,

we were brought to a stop by a protest in the form of a legal document, holding the managing partners personally responsible for the building of a new mill. This, of course, was an unexpected stunner, and all work was suspended.

One Sunday morning Mr. Townsend came down to the mill where I was alone, and brought with him the legal protest and read it to me. After all these years, no person other than myself can fully appreciate the trying position the managers were in. On the one hand I was urging them to go on and build a mill on an untried plan, and absolutely refusing to build the two-high geared mill they asked for, feeling that such a mill would only in a small way mitigate the troubles we had gone through, and that the money spent on such a plant would be thrown away. On the other hand, there was a strong party of stockholders protesting in the most positive manner against going on with my plans, and notifying the managers that they would hold them personally liable for all the loss and damage that might grow out of their unwise action, as they considered this action to be, in adopting a new and untried method that was against all practice in this and the old country, from which at that time we obtained our most experienced iron-makers. Besides, prominent iron-makers in various parts of the country had said to Mr. Morrell that the whole business would end in a failure, and that man Fritz would ruin them. The heaters and rollers were also opposed to my plans, and they appointed a committee to wait on the managers and to say to them that the three-high train would never work; that they themselves would suffer by reason of its adoption, but that if the managers would put in a two-high geared train, which was the proper thing to do, the mill would go all right.

As I look back to that eventful Sunday morning long years ago, when, sitting on a pile of discarded rails, with evidences of failure on every side, Mr. Townsend and myself quietly and seriously talked over the history of the past, the difficulties of the present and the uncertainties of the future, I cannot but feel, in view of what has since come to pass, that it was not only a critical epoch in the history of the Cambria Iron Company, but, as well, the turning point in my own life. For, as Mr. Townsend rose to leave, after a long conference, he turned to me and said: "Fritz, go ahead, and build the mill as you want it." I asked: "Do you say so officially?" To which he replied: "I will make it official." And he did so.

I want to avail myself of this opportunity to say that to no other person so deservedly belongs the credit, not only of the introduction there of the three-high roll train, but of the subsequent wonderful prosperity that came to the Cambria Iron Company, as it does to E.Y. Townsend, then its vice-president. Notwithstanding I had now the consent of the company to go on, many of my warmest friends, some of whom were practical iron-workers, came to me and urged me not to try so foolish an experiment. They said I had taken a wrong position in refusing to build the kind of a mill the company wanted; that in all probability the mill I was getting up would prove a failure, and, being a young man, my reputation would be ruined for life. To this I replied that possibly they were right in what they said, but that I had given the subject the most careful consideration, and was ready to take my chances on the result. The work was now pushed on as fast as possible.

In the construction of the rail-train I made a radical departure from the old practice, which was to provide breaking-pieces here and there. I tried to make everything so strong that nothing would break. One of the previous methods was to make coupling-boxes and spindles so that they would break when any extra strain would come on them, and the driving spindle had a groove cut around it so that it would be sure to break before the rolls. The result was the constant breaking of some of these safety devices.

In addition to all these devices there

was what was called a breaking-box on top of the rolls which held the roll in position, which was made hollow, so as to crush if the strain was too great. I directed the pattern-maker to make it solid. The head roller, seeing the pattern was solid, went to the pattern-maker to have it changed and made hollow, as he supposed it had been made so by mistake, but the pattern-maker refused to alter it, as he said the "old man" (as they called me forty years ago) had ordered it to be made that way. "Well," said the roller, "the old man has gone crazy; and if that box is put in as it is, the mill will be smashed to pieces, and I am going to see him about it," which he did, and, of course, I told him the box was going in solid, as I would rather have one grand old smash-up once in a while than be constantly annoyed by the breaking of spindles, couplings and breaking-boxes; to which he replied: "Well, you'll get it."

The new mill having been prepared and being ready to put in place, the old mill was stopped on the evening of July 3, 1857, and after the Fourth I commenced to tear the old mill out and put the new one in, and also to put in the new engine, while at the same time I remodeled everything about the rail-department, and raised the floor-line 2 feet. On the 29th of the same month everything was completed and the mill was ready to be started. I need not tell you that it was an extremely anxious time for me, nor need I add that no engraved cards of invitation were sent out, that not being the custom in the early days of iron-making; and, indeed, if it had been it would not have been observed on that occasion. As the heaters to a man were opposed to the new kind of a mill, we did not want them about at the start. We however secured one out of the lot, who was the most reasonable one among them, to heat the piles for us, and we kept the furnace smoking for several days, as a blind.

At last, everything being ready, we charged six piles. About ten o'clock in the morning the first pile was drawn and went through the rolls without the least hitch, making a perfect rail. You can judge what my feelings were as I looked upon that perfect and first rail ever made on a three-high mill; and you may in part know how grateful I felt toward the few faithful men who were about me, and who had stood by me during all my trials and difficulties, among whom were Alexander Hamilton, the superintendent of the mill, and Thomas Lapsly, who had charge of the rail-department, Wm. Canam and my brother George.

We now proceeded to roll the other five piles. When two more perfect rails had been rolled, we were obliged to stop the engine, for the reason that we were so intently watching the rolls that the engine had been neglected, and, being new, the eccentric strap, for want of oil, got hot and bent the eccentric rod so much that the engine could no longer be worked. As it would have taken some time to straighten the rod and reset the valves, the remaining piles were hauled out from the furnace on the mill floor.

About this time, the heaters, hearing the exhaust of the engine, came into the mill in a body and from the opposite end to where the rails were. Seeing the unrolled piles lying on the floor, they took it for granted that the new train was a failure; and their remarks about it were far from being complimentary. Mr. Hamilton, coming along about that time, and hearing what they were saying about the mill, turned around, and using language more pointed than polite, told them that if they would go down to the other end of the mill, they would see three handsomer rails than had ever been made in their country. The next day, which was Friday, we ran all day, and at night put on the regular night-turn.

Everything worked well up to noon of Saturday, it being our custom to stop rolling at that time. About six o'clock in the evening, Mr. Hamilton and myself left the mill, and on our way home we congratulated each other on the fact that our long line of troubles and disappointments was now over.

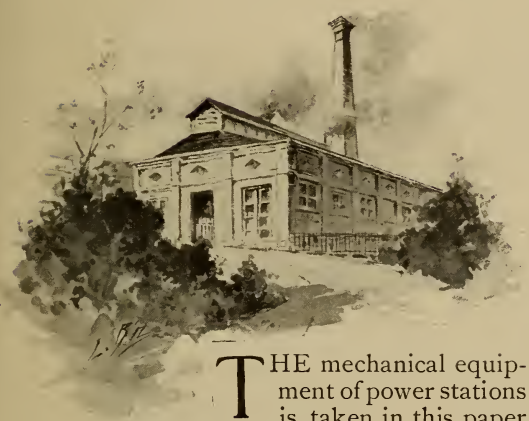
About an hour later I heard the fire alarm whistle blow, and rushing back to the mill found it one mass of flame from one end to the other. In less than one hour's time the whole building was burned to the ground, and a story started that the new machinery was a total failure, and that we had burned the mill to hide our blundering mistakes.

The situation of affairs on that Saturday night was such as might appall the stoutest heart; the result of our labors and anxieties lay there, a mass of black and smoking ruins, and the money that had been so hard to get, with which to build the new works, was gone. The prospect was gloomy, but there was one gleam of light amid all the darkness; and that was the pile of new and perfect rails which, as Hamilton had said, had neven been beaten in Wales, from which country most of the iron rails used here came. Above all, the mill had been tried and found to work magnificently, and it was these two facts that gave us all fresh courage and enabled us to rebuild the mill.

The following day, Sunday, was devoted to rest and to thinking over the matter; at any rate, it was not spent in the mill. On Monday morning we commenced to clear up the wreck and to begin the work of rebuilding. In four weeks from that time the mill was running, and made 30,000 tons of rails without a hitch or a break of any kind, thus making the Cambria Iron Company a great financial success, and giving them a rail-mill far in advance of any mill in the United States, a position they held unquestioned until the revolutionary invention of Sir Henry Bessemer came into general use, and steel rails pushed to the wall the rails previously made of iron. I do not intend to speak of the wonderful change this invention of Sir Henry Bessemer brought about, nor of the enormous increase in the production of rails it made possible. It is but just to say that some credit for this great increase is fairly due to the introduction of the three-high roll-train, first erected, amid the most discouraging conditions, in the mill of the Cambria Iron Company at Johnstown thirty-seven years ago.

# THE MECHANICAL EQUIPMENT OF POWER STATIONS.

*By Professor R. C. Carpenter.*



THE mechanical equipment of power stations is taken in this paper to include the subject of prime movers and such transmission machinery as may be required. In other words, that portion of equipment that belongs peculiarly to the province of the mechanical engineer. The term power station, too, is here restricted in application to those buildings where the power is transformed from mechanical to electrical energy for use on electrical railroads. Much that is said, however, would be equally applicable to the equipment of electric light stations or to a power house for cable railroads. The subject, from its very nature, is a broad one; consequently, only the most general statements can be indulged in within the present limits.

The power required for electric railroad service must possess three important requisites which I would name and arrange as follows, in their order of importance: Reliability and certainty of operation, uniformity of speed and economy.

The service rendered by an electric railroad being a public one, interruptions to traffic are exceedingly detrimental, causing loss not only to the revenues of the road, but to the travelling public and all concerned. In nearly every case a stoppage of the line is regarded as a public calamity, and failure to run cars might, in some instances, render the company liable for damages. For this reason I would place as the first and most important requisite the reliability and certainty with which power can be furnished.

Uniformity of speed of the driving mechanism is necessary because the voltage, or intensity, of the electric current depends upon the rate of rotation. This is not, probably, of so much importance in power stations as in lighting stations, since a change in voltage, unless of extreme amount, is not so detrimental to good service as in the former. Indeed, it may be said that the winding which is put on many electrical generators is so arranged that, even though the speed were to remain perfectly constant, the voltage would increase fully ten per cent. while the load was increasing from nothing to a maximum.

Just what variation of speed might be permitted in the engine without producing detrimental results is one that the writer cannot definitely answer; but it is quite certain that if the variation does not exceed five per cent. it is likely to pass unnoticed. The regulation in all cases must be sufficiently close to meet the demands for the class of power required. In some instances little or no variation can be permitted,

ROLLA C. CARPENTER is, at present, associate professor of experimental engineering at Cornell University and, for a number of years past, has practiced also as a consulting engineer. He has written much on technical matters, in the shape of papers before engineering societies, and is the author, also, of "A Manual of Experimental Engineering."

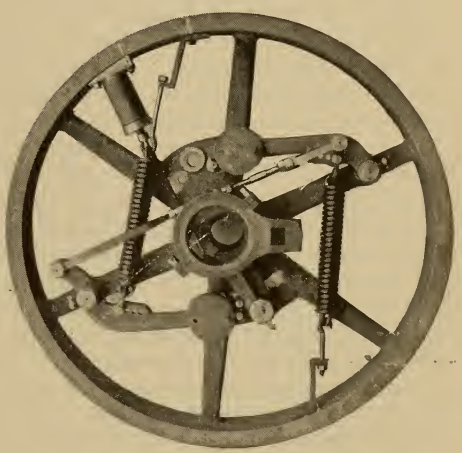
AN AUXILIARY STEAM PLANT FOR A WATER POWER STATION AT ITHACA, N. Y.

in which case the matter of regulation becomes one of extreme importance. The usual specifications for steam engines, drawn to-day, permit an extreme variation of two per cent. A few makers of engines guarantee the engine not to run one revolution, per minute, slower than its normal speed for any variation in load. The first requirement, although apparently much less rigorous than the second, is in reality more difficult of accomplishment.

Within a few weeks my attention has been called to a plant in which, under existing conditions, the extreme variation in speed, instant by instant, was fully 25 per cent., yet the revolutions per minute, as recorded by an instrument of undoubted accuracy, did not vary one per cent. For the cause of this apparent anomaly we have only to consider the structure of the governing apparatus. In every machine this apparatus consists of some moving mechanism which is affected by centrifugal force, sometimes assisted by inertia, so that a supply valve is opened or closed, as required to produce uniform speed. The mechanism in question cannot act until some change in speed has occurred; it may act very quickly, or it may act slowly, but in every event it acts irregularly, so that the most perfect motion, instead of being uniform, consists of a series of accelerations and retardations. Minute by minute the average speed may be perfect, but the average may not be and often is not any measure of the uniformity of the speed.

Methods of regulation which should act independent of changes in speed have been proposed and even put into actual use, but so far none have succeeded in gaining and maintaining a permanent footing in business. The electric current generated has been used to regulate the speed by variation in quantity or intensity. Governing by change in voltage is open to the same objection as that urged against the use of centrifugal force, since under ordinary conditions the voltage is a function of the speed, and changes only after the speed has increased or diminished. Governing by the load, or by the amount of current produced, is not open to these objections, since it is possible that contemporaneous changes of the valve and load can be made, so that a certain valve opening should be given for each load, which would be such as to maintain uniform speed.

Difficulties arise with this method of governing, due to changes in steam pressure or intensity of motive force, which act to prevent a given valve opening, corresponding to a definite load, from producing uniform speed. This problem is a difficult one to solve when steam is the motive force, but it offers a most promising method of governing where water, acting with a constant head, is used. On the whole, while these methods of governing are promising, it is a question whether or not they can be practically and successfully applied. The principle of weighing the load, with the governor, has never, so far as the writer knows, proved fully successful in practice.



A MODERN STEAM ENGINE GOVERNOR.

The third condition, that of economy, is one of great importance. No plant will be operated for any length of time at a continual loss. Business principles require that the earnings of a plant shall pay operating expenses, repairs and a good interest on the investment. The question is a difficult one to treat in a general way, since the conditions and local surroundings have much to do

with questions of economy. The economy is affected by interest rates on money, price of fuel, cost of labour, all of which circumstances vary much at different times and in different localities. The interest expenditures become of greater or less importance as the amount of business done is great or small. In all cases the cost should receive the most careful consideration from the engineer, but in no case should the fact be neglected that low first cost may mean high operating expenses which are likely to more than offset interest charges on a plant of better character.

Three general methods of arranging machinery of power stations are common in the United States. In one the power is transmitted from the prime mover to a line shaft and thence, by belting, to the dynamos. This we will call the line shaft system. In another the power is transmitted by a belt or rope from the prime mover directly to the dynamo. This we will term the direct-belted system. In the third the shaft of the dynamo or generator is directly connected to the prime mover and has the same speed of rotation. This we call the direct-connected system. Regarding these several systems it may be said that local conditions or surroundings may be such as to render it advisable to adopt one or the other. The writer, however, believes that it will be seldom or ever necessary under present conditions of manufacture to adopt or use the line shaft system. That system is objectionable for various reasons.

First, a large amount of power is consumed in moving the line shaft; hence, it adds very largely to the operating expense of the station. The power absorbed by the shaft is generally much more than supposed, depending upon the speed of rotation, the amount of power transmitted, and the length and weight of shafting. In one or two tests of line shafts made by the writer the power absorbed in running the shafting was never less than five per cent. of the total output.

Second, the line shaft is very expensive in first cost, if well constructed and properly fitted with friction clutches and friction clutch pulleys, so that the various machines which are connected to it can be started or stopped when required.

Third, the line shaft is expensive to maintain, especially when it runs at high speeds and is provided with friction clutches.

In some experience in station management, where a long line shaft, provided with a number of friction pulleys, is in use, the expense for repairs and renewals has been great—larger than that of the whole station. This shaft was constructed at great expense by one of the best firms, and is a fair representative of such systems in stations where the machinery is worked nearly to full capacity. It is also hard to arrange a system of this character in such a way that an accident to some portion of the line shaft will not cut out or prevent the running of many important machines. While the heavy line shaft may, under certain circumstances, be necessary, I shall always consider it as a waste of mechanical force and of lubricants, and a direct cause of extra operating expense.

The direct-belted system is to-day the cheapest in first cost, and, in many respects, the most satisfactory to operate. The arrangement of the generators, distinct from the prime movers, and connected by flexible connections, makes it possible to repair accidents with great facility and convenience. In general, with this system, only one or, at most, two generators can be driven from an engine without the use of riding belts. With the condition of the market as at present, however, with generators available of any size required, this matter is of little practical importance.

The direct-connected system is, without doubt, the ideal system, since transmission losses are eliminated and the power occupies a minimum amount of space. The cost to-day would be about 20 per cent. in excess of the direct-belted, but not essentially greater and possibly even less than that of a well constructed line shaft system. The American practice in building direct-

connected machines is to extend the main shaft of the engine and suspend the generator armature on the end either with or without an out-board bearing. The English system is somewhat less rigid, the engine shaft being connected to the dynamo shaft with a coupling.

My own feeling is that while the American practice gives a more compact machine, the English practice shows better mechanical engineering and gives a form which is more easily handled and can be run with less operating expense. The American practice throws a heavy weight on the main bearing of the engine and places the generator in a position where it must be protected from oil. When repairs are necessary to either engine or generator, much difficulty is experienced in reaching and taking out the defective part. In the mind of the writer, if the machines were constructed entirely separate, supported by independent bearings, and were connected by coupling the main shafts of each, the combined machine would be much more satisfactory, could be operated for less expense and, in every way, would represent better engineering than the present American practice.

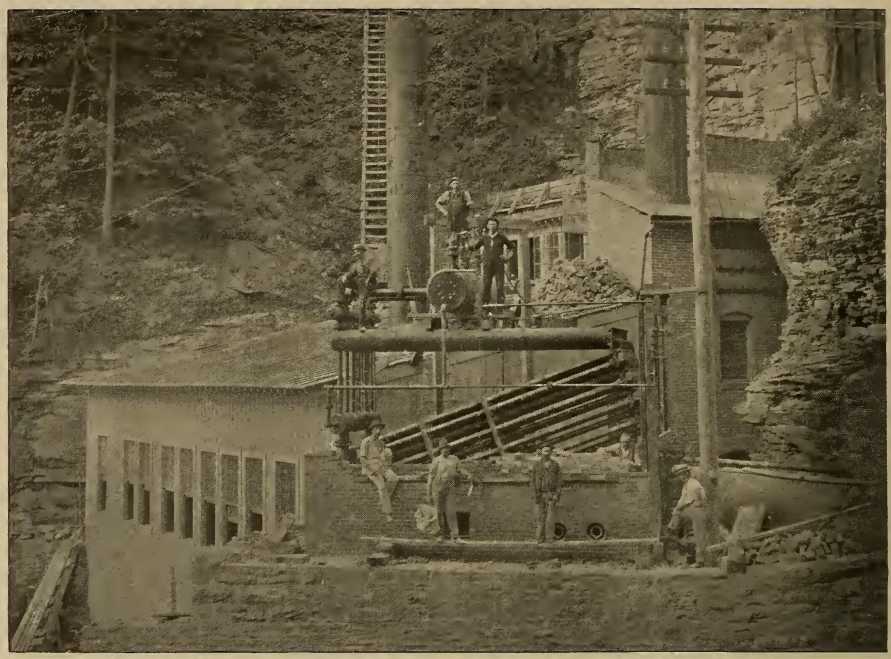
The proper proportioning of the units of power is of great importance. The least first cost is caused by making the units of the largest size and equal in number. Units of large size, if fully loaded, can be run with less operating expense than numerous small units. On account of the danger of accident which might cause stoppage of the plant, it is necessary to have more than one working unit, and it is desirable to have at all times one unit, representing engine and generator, not running, but standing ready to be put in operation at any instant. If the units of the station are very large, the cost of this relay plant becomes a great portion of that of the whole plant and a great fixed charge against the station. If the load is extremely variable, but within reasonably fixed limits for different portions of the day, this variation being of considerable magnitude, it might be safe to have two working units, which would both be used at the periods of heaviest loads, while one only would be used when the load is light.

The present construction of both engines and dynamos, as compared with that of a few years ago, is such as to render the danger of accident very much less than in the past, but it is certainly true that no engine or no machine can safely be relied on for continuous work unless it can be stopped long enough each day for thorough cleaning and inspection. Taking the construction of engine and dynamo as they are built to-day, and the liability to accident with the present machine, I would consider that the ideal station should have about three working units and one relay, in order to give practical insurance against any accident which would cause stoppage of the plant with least expenditure for power.

It is necessary for economical operation that the load on the engines be as nearly a full load as possible; consequently, the size of unit must be properly proportioned to the work to be done. It should be remembered that the engine is more economical with an over-load than with an under-load. The number of units will also be affected by the minimum size. It is not probable that for any railroad power station it would be advisable to put in, for power purposes, a generator smaller than of 100 kilo-watt capacity, which will require an engine of 150 horse-power to drive it. Either engine or dynamo can, if properly constructed, be worked 25 or 30 per cent. over the rating.

As to the character of the power, we have, in a general way, the choice of three kinds of prime movers, which may be classified as follows: First, water motors; second, direct heat engines, gas or oil; third, steam engines.

Water power is usually available only in certain localities, when the plant can be located close to the water. The feasibility of transmitting power a long distance will soon be experimentally tested at Niagara, and this may demonstrate economical methods which can be used with success in other localities. At



ANOTHER VIEW OF THE AUXILIARY STEAM PLANT SHOWN ON PAGE 474.

present we would be assuming a great risk of financial failure were we to attempt to transmit our power much further than eight or ten miles. As the matter stands at present, practical electrical transmission for long distances is expensive in first cost and will cause large interest expenses which may offset extra expenditures due to fuel. In general water power is available only in favored localities, but it is quite probable that it has not been utilized in the past to an extent that has been warranted by the existing conditions.

As compared with a steam plant, water power possesses the disadvantages of being less reliable, more difficult to regulate, but vastly more economical to operate. It is true that large powers, like Niagara, are as reliable as any steam plant can be, but the great majority of the streams to which we must look for power are subject to periodical seasons of flood and drouth. If the plant is designed to utilize the average power of the stream, auxiliary power, sufficient to compensate for lack of water in the dry season, must be put in and must stand ready for emergency use.

In general, the streams in our latitude give more or less trouble in the winter from anchor and slush ice, which is sometimes so troublesome as to cause a stoppage of the entire plant for a short time. These considerations make it desirable, and even necessary, to have a relay steam plant of a capacity equal to that of the water wheels, ready for immediate use. We have, then, an increased first cost due, first, to the water power, and, second, to that of the auxiliary or steam power plant.

The cost of a water power plant will depend entirely upon conditions. The expenditure for the machinery proper is comparatively small, but the plant must include dam, head gates, flume, transmission machinery, and the necessary buildings, all of which tend to make the plant much more expensive in first cost than that of a steam plant alone.

The kind of wheel ordinarily used for this purpose is mounted on a horizontal axis, and is connected to the tail race

by a draft tube which is supposed to remove atmospheric pressure and prevent loss of head. Two wheels are frequently mounted on the same shaft and are arranged so that the horizontal thrust of one is opposed by that of the other. On the axis with the wheels driving pulleys are mounted, and belting, hemp or wire ropes are used for transmission. My own experience is in favor of hemp ropes, especially for cases in which the position of driving and driven shaft is fixed. These ropes run very steadily, make very little noise, and the system of taking up the slack by passing it over an auxiliary pulley, balanced by a weight, is a practical and extremely convenient way of reducing slipping and taking up the stretch of the rope.

When water wheels are used it is generally necessary to adopt a line shaft system of power transmission, although direct-connected systems are, in some cases, possible. This seems especially necessary when the steam plant is standing as a relay, in order that either one or the other may be used as required. In this case the low cost of power would, no doubt, render the expense of operating the line shaft small, and the system would be less objectionable than when steam is used as a motive power. The draft tube is theoretically perfect for a length of 33 feet, but air is likely

FLUME FOR A WATER POWER STATION AT ITHACA, N. Y.

to be drawn in through the stuffing boxes around the axles of the wheels, and by leakage, so that a large percentage of this head is lost in practice. For that reason the draft tube should be made as short as possible.

Water wheels on vertical axes were formerly used to a great extent for power purposes, but they have generally been superseded by the wheel resting on a horizontal axis, as described. A prominent exception to this is found at the Niagara Falls power station. In this case wheels of 5000 horse-power each are at the lower ends of vertical hollow shafts about 160 feet in length, and the armatures of the dynamos are rigidly mounted at the upper ends of the same shafts. The weight of each shaft and its supplementary machinery is supported by water pressure, so that the ordinary difficulties pertaining to supporting a vertical shaft will be eliminated. This is an illustration also of a direct-connected water power system. It might frequently be possible to connect the horizontal axes of water wheels directly to dynamos, thus giving a direct-connected system of the horizontal type.

The regulation of water wheels is usually affected by a train of gears, operated by a belt connected to the main shaft. The direction of motion of the gear operating the gate is changed by a pawl or dog which is engaged by a ball governor. If the speed drops too low, the pawl on one side engages, so that the gate is opened wider; if the speed is too high, another pawl engages, so that the gate is closed.

In other forms of governors the pawls are connected electrically with the centrifugal governor. This has the advantage of flexibility in its location, as the governor can be located at a distance from the wheels. The governors usually operate the main gates of the wheel, but in the Reprogal-Pritchard governor, which is now in use at a power station at Ithaca, N. Y., a special gate is made by attaching to the draft tube a concentric balanced cylinder, which closes on a seat below the tube. When this gate is closed the flow through the draft tube is arrested, and the water is backed up into the wheel, stopping its motion. In the operation of this governor the gates above the wheel are wide open, so as to throttle the water supply as little as possible. This gate has certain advantages over the one directly above the wheel, but it is not subjected to constant pressure, and consequently equal increments of opening will not give equal changes in power.

In a governor of recent design, the pawls which define the direction of motion of the gate are operated by changes in the amount of current produced by the generators, there being a certain gate opening, found by trial, which gives the correct speed for any given load. The mechanism is so arranged that the gate is opened to that position required by the load for steady speed, by the electric current acting around a solenoid, the principle being that the demand for extra power is made at the same time with that for extra load, and, if the motion of the gate can be made sufficiently rapid, no change in speed will occur. In this governor the mechanism for moving the gate, instead of being a train of gears, will be a hydraulic cylinder and piston, similar to that used in operating elevators. The valves for admitting water are operated by the governing mechanism.

Any method of governing a water wheel is of necessity wasteful, for it becomes evident at once that no useful work can be done when the velocity of the moving mass of water is less than that of the wheel. When the regulation is performed by gates below the wheel the velocity of a column of water moving through the wheel is varied; when the regulation is performed by gates above the wheel, although the velocity in the flume is varied, that of the water passing through the wheel is not changed, since it issues under a constant head, but the amount of water discharged is varied. The efficiency of the wheel is low when a small amount of water is discharged; hence, both systems involve considerable waste.

The economy of water wheels varies to a considerable extent with the load,

although in this respect the latest design of wheels are much superior to the older wheels. The maximum efficiency is not far from 80 per cent. This usually falls to about 65 per cent. one-half gate opening, and to 45 per cent. for one-quarter gate opening. In some of the best designs of American wheels the efficiency in passing from half gate to nearly full gate is increased less than 20 per cent., and maximum economy is secured at seven-eighths full gate opening. As a rule, however, a wheel is very inefficient when worked at low loads, and is especially inefficient if the load rapidly changes in amount.

The average efficiency transferred from hydraulic to electric power is very small in electric railroads. This is partly due to the losses in transmission machinery and of conversion from mechanical to electric power, but largely also to the fact that the wheel is worked under very inefficient conditions. In a test made at the Ithaca power station, where water is used under a head of 95 feet, the average efficiency of electrical output, compared with that supplied in the water, was about 30 per cent, the maximum rising to 56, and the minimum falling to 16. To secure best economy it is of great importance to have the wheels proportioned so that they can be operated under full load during the greater portion of the time.

The gas engine and similar types of direct heat engines have been used in Europe to a considerable extent on a large scale to furnish motive power for dynamos. These engines, to be operated economically, require the construction of a plant to produce heating gas, and, in such a case, the economy, estimated from the actual coal consumed, has been 20 per cent. higher than that ever obtained from the best steam engines. The producer gas plant, although costing more, is analogous to the boiler in the case of the steam engine. The statistics of a large plant of this kind, in France, show that the cost will compare favorably with that of a complete steam plant.

In the United States one gas engine plant of 300 horse-power has been in successful operation at Danbury, Conn., for the past two years. The engines, of 100 horse-power, have cylinders 14½ inches in diameter by 24-inch stroke, and run at 165 revolutions. They were built by the Otto Gas Engine Works of Philadelphia. The direct heat engine will prove, in a short time, a formidable rival of the steam engine. It has already passed it so far as economy is concerned.

The steam engine is to-day the most reliable prime mover available. Its design has been the subject of years of study and experiment by the best engineers that the world has ever produced. Its manufacture has given employment to the best artisans. Capital, in almost unlimited quantities, has united in providing facilities in the way of convenient buildings and well finished tools for its construction. No machine turned out by man has, in fact, received greater attention in design, or higher skill in producing, than the steam engine.

It is built by various shops in a myriad of forms. Any style of construction, any peculiarity of arrangement, can be secured from reputable builders and without special design. In other words, steam engines can be purchased well built and well designed to meet any special demand.

Steam engines are designed heavy for the especial work of producing power for power stations. In the first electric stations equipped larger engines than were really needed were provided. These engines, having rather light working parts, failed to give satisfaction, both because of lack of economy and of frequent breakage. In the first power stations the capacity of the engines was large, perhaps 30 per cent. in excess of the dynamo capacity. This condition was such that the engine rarely had a full load and never an over-load. To-day the engines sold for this purpose can be expected to work to 25 or 30 per cent. over their rating without drop of speed, and the engine capacity will be sufficient if equal to dynamo capacity, increased by the necessary transmission and transformation losses. An excess

*Probable Water Consumption per Indicated Horse-Power per Hour for Various Classes of Engines with Different Loads.*

| Class of Engine. | Gauge Pressure. | General Equation of Steam Consumption. Value of $x$. | Ratio of Load to Rated Capacity. 1-10 | ¼ | ½ | ¾ | 1 | 1¼ | 1½ |
|---|---|---|---|---|---|---|---|---|---|
| | | | 10 | 4 | 2 | 1.33 | 1 | 1.25 | 1.50 |
| | | | Lbs. of Water per I. H. P. per hour. | | | | | | |
| Throttling..Non-Condens'g | 80 | $22.2\sqrt{x}+17.8$ | 88.8 | 62.2 | 49.6 | 43.7 | 40.0 | 42.8 | 45.2 |
| Automatic.. " | 80 | $14.2\sqrt{x}+17.8$ | 63.0 | 46.2 | 37.9 | 34.2 | 32.0 | 33.7 | 35.2 |
| " . . " | 100 | $12.9\sqrt{x}+16.1$ | 56.8 | 41.9 | 34.4 | 31.0 | 29.0 | 30.5 | 31.9 |
| Corliss Simple " | 80 | $12.2\sqrt{x}+17.8$ | 56.4 | 42.2 | 35.1 | 31.9 | 30.0 | 31.5 | 32.8 |
| Compound Automatic " | 100 | $9.8\sqrt{x}+16.1$ | 47.1 | 35.7 | 30.0 | 27.5 | 25.9 | 27.1 | 28.1 |
| " " " | 125 | $8.6\sqrt{x}+14.4$ | 41.6 | 31.6 | 26.6 | 24.3 | 23.0 | 24.0 | 24.9 |
| Corliss Simple.Condensing | 80 | $13.7\sqrt{x}+9.3$ | 51.5 | 36.7 | 28.7 | 25.1 | 23.0 | 24.6 | 26.1 |
| Compound Automatic " | 100 | $10.2\sqrt{x}+8.8$ | 41.0 | 29.2 | 23.2 | 20.6 | 19.0 | 20.2 | 21.3 |
| " " " | 125 | $9.2\sqrt{x}+8.3$ | 37.3 | 26.7 | 21.3 | 18.9 | 17.5 | 18.6 | 19.6 |
| Corliss Compound " | 100 | $8.7\sqrt{x}+8.8$ | 36.4 | 26.3 | 21.1 | 18.8 | 17.5 | 18.5 | 19.5 |
| " " | 125 | $7.7\sqrt{x}+8.3$ | 32.7 | 23.7 | 19.2 | 16.6 | 16.0 | 16.9 | 17.7 |
| Triple Expansion..... | 125 | $6.2\sqrt{x}+8.3$ | 27.9 | 20.7 | 17.1 | 15.5 | 14.5 | 15.2 | 15.9 |
| " " ..... | 150 | $5.85\sqrt{x}+7.9$ | 26.4 | 19.6 | 16.2 | 14.6 | 13.75 | 14.4 | 15.1 |

NOTE: $x$ = actual horse-power divided by rated horse-power.

*Probable Water Consumption per Delivered Horse-Power for Various Classes of Engines with Different Loads.*

| Class of Engine. | Gauge Reading. | [1] Ratio of Indicated Load to Rated Capacity. 1-10 | ¼ | ½ | ¾ | 1 | 1¼ | 1½ |
|---|---|---|---|---|---|---|---|---|
| | | Lbs. of Water per Delivered H. P. per hour. | | | | | | |
| *Non-Condensing.* | | | | | | | | |
| Throttling Simple.... | 80 | Friction Load D. H. P. = O. 103. | 74.5 | 50.5 | 44.5 | 46.6 | 48.5 | |
| Automatic " .... | 80 | 77.0 | 47.5 | 39.6 | 35.6 | 36.6 | 37.8 | |
| " " .... | 100 | 70.0 | 43.0 | 35.8 | 32.3 | 33.2 | 34.2 | |
| Corliss " .... | 80 | 70.5 | 43.8 | 36.8 | 33.4 | 34.2 | 35.2 | |
| Automatic Compound | 100 | 59.5 | 37.7 | 31.8 | 28.8 | 29.4 | 30.1 | |
| " " | 125 | 52.7 | 33.3 | 28.1 | 25.6 | 26.1 | 26.7 | |
| *Condensing.* | | | | | | | | |
| Corliss Simple..... | 80 | Less than Friction Load. 73.4 | 38.3 | 30.1 | 26.3 | 27.4 | 28.5 | |
| Automatic Compound | 100 | 58.4 | 31.0 | 24.8 | 21.7 | 22.5 | 22.2 | |
| " " | 125 | 53.4 | 28.5 | 22.7 | 20.0 | 20.7 | 21.4 | |
| Corliss " | 100 | 52.6 | 27.2 | 22.6 | 20.0 | 20.6 | 21.2 | |
| " " | 125 | 47.4 | 25.6 | 19.9 | 18.3 | 18.8 | 19.3 | |
| Triple Expansion.... | 125 | 41.4 | 22.8 | 18.6 | 16.6 | 16.9 | 17.3 | |
| " " .... | 150 | 39.2 | 21.6 | 17.5 | 15.7 | 16.0 | 16.5 | |

[1] The numbers express the proportion of the indicated horse-power developed to the rated indicated horse-power.

of power above this will not only add to the first cost, but to the running expenses as well.

Steam engines can be classified in three ways, viz., by the method of governing, by the kind of valve gear, and by the arrangement of cylinders.

In the method of governing we have two classes :—Throttling engines, in which the pressure of the steam entering the engine is reduced ; automatic engines, in which the admission valve is moved by the governing mechanism and the steam pressure is not reduced.

Of this latter kind we have again two classes : A. Engines with a simple slide valve, rigidly attached to the governor in the fly wheel, the governor being a positive-motion device. In this class we may embrace, with slight qualification, the Porter-Allen engine, in which there is a belt-driven governor attached to a link. B. Engines with a governor actuating a release gear which permits the valves to be closed. To these belong the Corliss, Wheelock and Greene engines.

In the United States the throttling engine has not been used to any great extent for this work. The Willan's engine, however, which has met with great success in England, and is now manufactured in America also, is provided with a throttling governor. This type of governor is usually sold only with an inferior class of engines, and is generally of inferior workmanship and design. By running these governors at a high rate of speed close regulation can be obtained. The question of relative economy is still open, but this is probably not much different from that of the automatic slide valve engine when the engines are equally well built.

The two classes of automatic engines are usually known as slow speed and high speed, this having reference to the number of revolutions ; but the piston speed of the two classes is often about the same. The high speed automatic engine has superior regulation, but is lacking in economy. This is not due to speed, since high speed is an element of economy, but to valve motion. The quick-closing motions of the Corliss, Wheelock or Greene engine valves, the sharp cut-off and perfect expansion curves more than offset any advantages due to high speed in the other class of engine. The automatic engine with balanced valves is likely to leak steam from the steam chest into the cylinder, so that we never secured, and probably never will secure, a high economy from this engine.

The high speed enables a small engine to do a great amount of work ; consequently, this class of engines is much lower in first cost than the other and has the advantage of low interest charges to make up and offset any excess in operating expense.

The passing of steam from cylinder to cylinder, as in the compound and triple expansion engine, reduces the loss of heat and increases the economy to a great extent. The compound and triple expansion engines can be regulated extremely close, and the economy remains more constant for variations in load than in the simple engine. The gain in economy of the triple expansion engine over the compound will not warrant the additional expense with the steam pressure in common use to-day, but the compound engine will be found, when boiler plant is taken into consideration, to be cheaper in first cost than the simple engine and to require less money to operate it.

The steam boiler plant is of great importance, and the economy of the station will largely depend upon the kind of boiler, its accessories and furnace. While the writer must admit that, considering its importance, this portion of the steam plant is likely to be neglected, yet space will not permit a discussion of this important branch of the subject. It may be said briefly that there is little advantage in the way of economy of one kind of boiler over another ; that water tube boilers are much safer to operate, take up less space, and are quicker steamers than fire tube boilers. On the other hand, they are much more expensive, are not so readily cleaned and do not have so large a reserve of water to tide the plant over a period of excessive demand for steam.

*Cost per Horse-Power for a Plant of 500 Horse-Power.*

| Kind of Engine. | Cost of Engine Only. | Cost of Condenser. | Cost of Tubular Boiler Set. | Cost of Water Tube Boiler Set. | Pumps, Piping and Acces-sories. | Total Cost Per Horse-Power. |
|---|---|---|---|---|---|---|
| Simple High Speed Non-Condensing T..... | 7.0 | .. | 12.0 | .. | 5 | 24 |
| Simple High Speed Non-Condensing W. T..... | 7.0 | .. | .... | 20 | 5 | 32 |
| Tandem Compound High Speed Non-Condensing T..... | 11.0 | .. | 10 | .. | 5 | 26 |
| Tandem Compound High Speed Non-Condensing W. T..... | 11.0 | .. | .... | 16 | 5 | 32 |
| Tandem Compound High Speed Condensing T ..... | 10 | 3 | 7.2 | .. | 6 | 26.2 |
| Tandem Compound High Speed Condensing W. T..... | 10 | 3 | .... | 12 | 6 | 31 |
| Corliss Simple Non-Condensing T..... | 15 | .. | 10.8 | .. | 5 | 30.8 |
| Corliss Simple Non-Condensing W. T..... | 15 | .. | .... | 18 | 5 | 38.0 |
| Corliss Cross Compound Condensing T..... | 22 | 3 | 6.0 | .. | 9 | 40.0 |
| Corliss Cross Compound Condensing W. T..... | 22 | 3 | .... | 10 | 9 | 44 |

NOTE: T., represents tubular boiler; W. T., water tube boiler. One boiler horse-power is required for each horse-power of a simple non-condensing engine; 0.8 for a tandem compound non-condensing, and 0.6 for tandem compound condensing. For Corliss engines, the simple non-condensing requires 0.9 horse-power; compound condensing, 0.5 boiler horse-power.

*Yearly Cost per 100 Horse-Power, Fixed Charges and Fuel for Various Classes of Engines.*

| Kind of Engine. | First Cost 100 H. P. | Interest at 10 per cent. | Coal per H. P. Hour Lbs. | Coal per Year, 365 days of 12 Hours. Tons. | Yearly Fuel Expenses. | | | Fuel at $3 and Interest. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Coal, $2 per Ton. | Coal, $3 per Ton. | Coal, $5 per Ton. | |
| Simple High Speed Non-Condensing T..... | $2,400 | $240 | 4.5 | 985 | $1,970 | $2,955 | $4,725 | $3,195 |
| Simple High Speed Non-Condensing W. T..... | 3,200 | 320 | 4.5 | 985 | 1,970 | 2,955 | 4,725 | 3,275 |
| Tandem Compound T... | 2,600 | 260 | 3.6 | 787 | 1,574 | 2,361 | 3,935 | 2,661 |
| " " W.T. | 3,200 | 320 | 3.6 | 787 | 1,574 | 2,361 | 3,935 | 2,681 |
| Tandem Compound Condensing T..... | 2,620 | 262 | 2.5 | 547 | 1,094 | 1,641 | 2,735 | 1,903 |
| Tandem Compound Condensing W. T..... | 3,100 | 310 | 2.5 | 547 | 1,094 | 1,641 | 2,735 | 1,951 |
| Corliss Simple Non-Condensing T..... | 3,080 | 308 | 4.0 | 875 | 1,750 | 2,625 | 4,375 | 2,933 |
| Corliss Simple Non-Condensing W. T..... | 3,800 | 380 | 4.0 | 875 | 1,750 | 2,625 | 4,375 | 3,005 |
| Corliss Cross Compound Condensing T..... | 4,000 | 400 | 2.2 | 480 | 960 | 1,440 | 2,400 | 1,840 |
| Corliss Cross Compound Condensing W. T..... | 4,400 | 440 | 2.2 | 480 | 960 | 1,440 | 2,400 | 1,880 |

T. signifies tubular boilers; W. T. signifies water tube boilers.

The tables on page 482 give the steam consumption per horse-power-hour that can be expected from the various classes of engines for different boiler pressures. They were originally prepared by the writer for the American Institute of Electrical Engineers.

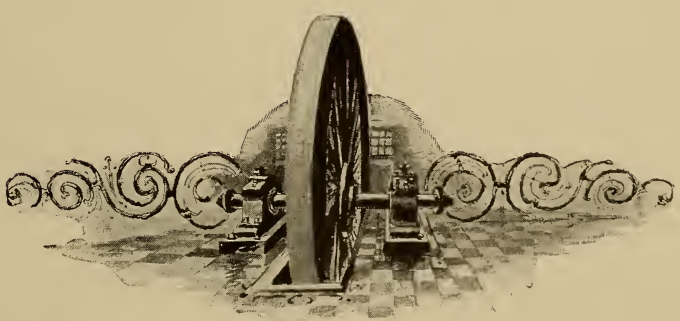
The table at the top of the page opposite, giving the cost per horse-power of different classes of engines and boilers, completely set, with feed pumps, etc., is based on actual prices for 500 horse-power, not including the building.

By combining these tables we can readily compute the interest and probable fuel expenses for the various classes of engines. This has been done in the table at the bottom of the opposite page, in which interest and depreciation are calculated at six per cent. Building expenses and attendance are not considered. In figuring the coal per indicated horse-power the engine is assumed to work at ¾ power and also that 7½ pounds of water are evaporated for one pound of coal

The annual operating expense, with fixed charges at 10 per cent. and fuel at $3.00 per ton, is decidedly in favor of the compound condensing engine. If real estate and buildings are not considered, as in the cases in the table, the results are in favor of the slow-speed and higher-priced engine. If real estate is expensive and buildings are costly, the difference in fixed charges on that account might make the yearly charges in favor of the high-speed engine.

The evaporation assumed in the table is doubtless six per cent. higher than is obtained in the average steam plant today, but it is no better than should be obtained with good fuel and careful management.

An average load for a power station engine of three-fourths the rating is high and indicates a better economy than can perhaps be secured in practice. The actual fuel consumption is likely to exceed that given in the table by 20 per cent., but as all the engines are assumed to be working on the same basis the comparative results are not affected greatly.



# MORE ENGINEERING FALLACIES.

*By Henry Morton, Ph. D.*

SINCE the publication of my paper in the January number of CASSIER'S MAGAZINE on "Engineering Fallacies," and, indeed, in consequence of such publication, some fallacies not directly included in my paper have been presented to the engineering profession in an editorial article recently published in the London journal, The Engineer. This article purports to comment on my paper on "Engineering Fallacies," but is, in fact, a defence of perpetual motion as a rational subject or field for the labours of inventors.

It is truly surprising to find such views ventilated in such a way and in such a journal, but the fact vindicates me in devoting as much effort as I have to elucidating the subject, and warrants the employment of further time and space in following up and expounding these additional fallacies. In the first place, I will quote what the editor of The Engineer has to say about his proposed form of perpetual motion machine :—

"Let it be supposed that the cylinder of a beam engine was removed and replaced by a series of very powerful magnets arranged around the piston. If now the first ring of magnets, and then the second and third, and so on, attracted the piston successfully, the engine would work just as though driven by steam.

"Let the magnets be permanent, and let the piston be surrounded by a cylindrical shield, which, while itself non-magnetic, would also cut off the influence of the magnets as it passed each on its way down.

"Under these conditions we would have a machine which would comply with the perpetual-motion man's desire. In one sense it would flatly contradict the conservation of energy theory—we should get power for nothing. The only thing needed is the magnetic shield. Now, why is it that no such shield exists? Is it because the existence of the shield would upset the conservation of energy? Again, let us suppose that a material existed which, placed between a body and the earth, would neutralize the action of gravity; perpetual motion would at once be ready to one's hand. Why does not such a material exist?

"If we give a little thought to the matter, it will be seen that the questions we have put cannot be answered. Thus, there is no reason known to mankind why gravity should not be intercepted, and if any inventor announced tomorrow that he had discovered or invented the material, no man living would be justified in calling him a liar on the ground that he said he had done what was impossible."

It would be hard for me to believe that such statements could be seriously put forth by a writer presumably acquainted with the first principles of physical science, but that I have them before me in the pages of The Engineer.

DR. HENRY MORTON, the president of Stevens Institute, one of the foremost engineering schools in America, has for many years been called upon to advise as a scientific expert in important investigations and patent litigations, and the efficiency of his work in these, involving difficult scientific problems, has gained for him an international reputation.

To all the questions stated or involved in the above quotations, however, a ready answer can be given by any one who appreciates and clearly understands the advice given by me at the opening of my paper. This was: "In the first place, though it may seem almost superfluous to mention such a thing, every engineer or investigator who undertakes the examination of any new project involving an assumed discovery of new laws or modes of action among the forces or nature, must hold with absolute confidence the great doctrine of the conservation of energy, with its direct corollary relating to what is technically called perpetual motion.

"This doctrine may be briefly stated as follows: No item of energy in the universe ever perishes, nor is any item of energy ever added to the existing supply. The only changes possible are the transformations of energy from one form into another. * * * * * It is as impossible to create energy as to create matter, and if any process is presented which claims to get out of a pound of coal more energy than it is known to possess, or out of the work of a horse more than its known amount, it should be regarded as precisely equivalent to the claim that 10 chairs could be made into 11 or 12 by some special grouping or arrangement. In other words, we should regard it as either a piece of legerdemain or of oversight and error of observation."

Guided by this advice, if an inventor announced that he had discovered a gravity shield, any one would be justified (not in calling him a liar, which propriety forbids) but in asserting most positively that he was mistaken, because, if what he said were true, he had a means at his command by which he could "get power for nothing," or in other words, create energy, or, again, increase the sum of energy in the universe, or, to express it in another way, secure a result contrary to the doctrine of conservation of energy; and that, in whatever form of words this was expressed, it would be as impossible as the turning 10 chairs into a dozen by arranging them in some particular order or grouping.

The same answer in substance could properly be given to the assertion that "there is no reason known to mankind why gravity should not be intercepted." There *is* abundant reason known to any one and to all those of mankind who understand the doctrine of the conservation of energy, because such an interception of gravity would involve the creation of energy, which is as little within human power as the creation of matter. And so on with all the rest of it. The engineer whose knowledge has made firm his faith in the conservation of energy is warranted in dismissing any such plans as the above on "a priori" grounds as unworthy of investigation with any other object than the detection of the fraud or mistake which they must involve.

Curiously enough I have an example touching The Engineer's plan for a magnetic motor within my own experience. In 1879 a Mr. Gary brought out in Boston a magnetic motor which was not only largely discussed in the daily papers, but had a long illustrated article published about it in so respectable a journal as Harper's Monthly.*

About that time I met the late Mr. Moses G. Farmer, whose work and inventions in connection with telegraph apparatus, dynamo-machines and electric lights is known over the world. He assured me that he had seen the Gary magnetic motors in operation, and expressed himself as satisfied that they were actually operative and that they demonstrated the possibility of obtaining energy from permanent magnets.

The "principle" of the Gary motor was the employment of a magnetic shield, which, being interposed and withdrawn at the proper time, would enable a permanent magnet to produce reciprocatory or rotary motion in pieces of soft iron arranged with proper supports to allow of and transmit their motion. In general terms, it was exactly the "principle" of the magnetic engine proposed by The Engineer. The magnetic shield used by Gary was

——* March, 1879, pp. 601 to 605.

a plate of soft iron which, as is well known, will act as a magnetic shield and cut off the attraction of a magnet from a neighbouring body capable of magnetic attraction.

Coming with such respectable surroundings and supported by such an eye witness, one might have thought that here was something worthy of serious consideration. Still, I was not shaken in my convictions as to the doctrine oi conservation of energy, but directed my inquiries at once to the question of fraud or mistake. A few questions elicited the fact that the models exhibited by Gary could be divided into two classes: 1. Those which worked or ran by themselves. 2. Those which required manual assistance to remove and replace the shield.

In the first class, Mr. Farmer told me, the magnets employed were electro-magnets, for the purpose, as the inventor represented, of securing greater power. Mr. Farmer assured me that he did not see any commutators by which the current might have been cut off and renewed as in an ordinary electro-magnetic motor, but he could not assure me that concealed arrangements for such commutation were not present. Of course, if arrangements for commutation of the current existed, the machine was simply an electro-magnetic motor like dozens of others, deriving its energy from the zinc consumption in the galvanic battery.

In the second class of models, having permanent magnets, the iron shield was removed and replaced by hand, the inventor stating that the power required for this was negligible. This was, however, a manifest error. The piece of iron used as a shield would be even more powerfully attracted by the magnet than the piece of iron to which it was intended that motion should be given by the magnetic attraction; hence, at least as much energy would be expended in moving the shield as could be developed by the action of the magnet on the more distant moving piece or pieces of iron. Such a structure would operate, in the sense of turning round or moving, but only with a power somewhat less than that expended by the hand in moving the shield.

As may be readily supposed I did not think the matter worthy of further investigation, but in reply to an inquiry from the secretary of the Franklin Institute at Philadelphia wrote as follows: "This so-called 'Gary Motor' comes before the public in a double character. First, as a perpetual motion machine, which is to do work without the transformation of energy. In this light I think we may at once dismiss it as a fraud or blunder, to take its place with materialization of spirits and other matters, which are not subjects for the investigation of scientific students.

"Secondly, however, Mr. Gary appears as the supposed discoverer of some new facts in reference to the action of magnets, which, though they certainly can no more enable us to create energy than to create matter, may add to our means of utilizing natural forces and existing sources of energy. In this view his claim of discovering what he calls a neutral line around magnets is worth investigation.

In looking into this matter, however, I find that he has only re-observed a set of phenomena which are so old as to have been described in the Principia of Sir Isaac Newton, Book II., Prop. XXIII., Scholium XVIII., where I find the following: 'The virtue of the magnet is contracted by the introduction of an iron plate, and is almost terminated by it; for bodies further off are not attracted by the magnet so much as by the iron plate.'

"All Mr. Gary's experiments, which will work, are readily explained by the well known principles of magnetic induction, by reason of which a piece of soft iron near a magnet is inductively magnetized by the same and reacts upon it, and thus contracts the virtue of the magnet, and neutralizes its action on exterior bodies. There is no evidence whatever of the existence of any neutral lines about a magnet, but the very experiments cited by Mr. Gary as proving it, simply demonstrate that in certain relative positions, the opposing actions of a permanent magnet and a

piece of soft iron, magnetized by induction from it. neutralize each other's effects upon a third magnetic body, such as a piece of iron or a compass needle.

"Fully to work out all the relations between the mutual actions of three such bodies in any case is of course a problem of considerable complexity, but by no means a new one, and, among others, a very able discussion will be found in the Philosophical Transactions for 1831, page 501, *et seq.*, by Sir Wm. Snow Harris under the title 'On the Power of Masses of Iron to Control the Attractive Forces of a Magnet.' An earlier memoir on the same subject by the same author appeared in the Edinburgh Philosophical Transactions for 1829, and the subject is also fully treated in the work entitled 'Rudimentary Magnetism,' by the same author, published in the Weale Series, 1850."

The above letter was published in the Journal of the Franklin Institute in May, 1879, vol. 77, p. 337. I have quoted it in full because the matter which it contains may be of use at the present time, when the great attention drawn to electro-magnetic motors is likely to bring into the field many inventors of the Gary class.

I need say no more in illustration of the practical utility to the engineer of a firm and clear conviction about the conservation of energy. The only way in which he can be assailed in that connection is by an attack upon his idea or definition of this fundamental doctrine. This the editor of The Engineer seems to appreciate, and he has consequently taken exception in a general and indefinite way to my definition, but without suggesting any other.

Though such unsupported and indefinite objections require no answer, yet, as the correct understanding and definition of this doctrine is at the very foundation of the whole matter, I will occupy a little more space in developing it. The first idea of the conservation of energy seems to have been entertained by Galileo and Newton, but it was first announced in a general form by Mayer, in 1842, as the result of theoretical considerations, and by Joule, in 1862, as supported by experiments begun in 1840.

The earlier writers frequently referred to it as the conservation of "force." Thus Helmholtz says: "From a similar investigation of all the other known physical and chemical processes, we arrive at the conclusion that nature, as a whole, possesses a store of force which cannot in any way be increased or diminished, and that, therefore, the quantity of force in nature is just as eternal and unalterable as the quantity of matter."

Rankine, in an article in the Philosophical Magazine in 1859, vol. 17, p. 250, draws attention to the ambiguity caused by the use of the word "force" in this connection, and proposes to substitute "energy," as defined by Dr. Young in his Lectures on Natural Philosophy (Lecture VIII.), and says: "The principle of the conservation of energy may be thus stated—In any system of bodies, the sum of the potential and actual energies of the bodies is never altered by their mutual actions." The term "energy" is now universally adopted among scientific writers for this subject, the term "force" being confined to expressing the idea of "stress" or "strain."

Turning to one of the latest authorities, I find the following definition of the conservation of energy, given by Clerk Maxwell: "The total energy of any body or system of bodies is a quantity which can neither be increased nor diminished by any mutual action of these bodies, though it may be transformed into any one of the forms of which energy is susceptible."

All these definitions and the one given by me are entirely in agreement and differ only in their forms, by which one or another may be more easily understood by different minds, and the facts which they state are as certain as the laws of gravitation or those of chemistry or of any other department of science in which they are the expression of universal accordant experience.

# CORROSION OF BOILERS AND STEAMSHIPS.

*By Wm. C. Ward.*

WITH steel, unprotected and exposed to the action of the weather and sea water, corrosion advances at the rate of one inch in depth in 82 years, while under the same conditions for iron the rate is one inch in 190 years. When exposed to the weather and fresh water, it is 170 years for steel and 630 years for iron. When always immersed in sea water, the periods are one inch in 130 years for steel, and one inch in 310 years for iron; and when always immersed in fresh water, the periods become 600 years for steel and 700 years for iron.

These conclusions, presented by the author in a paper recently read before the Goldsmiths' Institute Engineering Society, are the result of years of patient experiment and observation by Mr. Parker, of the British Board of Trade, and Mr. Phillips, of the Institution of Civil Engineers. They show us distinctly that steel, under similar conditions of working, corrodes much more rapidly than iron, and that salt water is a much more active corrosive agent upon either iron or steel than is fresh water.

Three theories have been started to explain the cause of this :—1. Want of homogeneity in the metal; 2. galvanic action between iron and steel when placed in contact; and 3. galvanic action between the steel and its covering of black oxide.

With regard to the first theory, it was stated that local action took place owing to the unequal diffusion of the manganese. But with the fact that steelmakers can now produce steel with a practically uniform distribution of the manganese, this theory had to "go by the board." The theory that steel is, by means of galvanic action, injuriously affected by iron in contact with it, was put forward when steel was in its infancy, was not trusted for riveting, and seems to have lasted as long as the blame could be thrown upon the rivets. But with the introduction of steel rivets and the continuance of the corrosion, this theory was entirely disproved.

In 1879 Sir Nathaniel Barnaby stated that when the surface oxide was left on steel plates its effect on the neighboring bared metal was as strong and continuous as copper would be; and in 1887 Mr. Railton Dixon gave before the Institute of Naval Architects his experience as to a vessel which had been built some eight years before, entirely of steel, and which had been greatly corroded. On looking at a portion of the interior plating of the after part of the vessel, where it had not been coated with paint or anything else, you could see the mill scale on it, just as it came from the rolls.

In 1882 Mr. Farquharson, on behalf of the British Admiralty, conducted a number of experiments to test the action of mill scale upon plates. They were very exhaustive, and the result was to establish beyond dispute that no pitting occurred in mild steel when freed from mill scale; that the loss of weight from corrosion of clean mild steel and clean iron did not differ much; and that the action of the mill scale is considerable and continuous, like that of a similar

WILLIAM C. WARD began his engineering education at an early age by becoming an apprentice to a prominent English engineering firm. Subsequently he attended at the Birkbeck Institute and City of London College, and later served in vessels in the Mediterranean and Baltic Seas. At present he is with the Boiler Insurance and Steam Power Company, Limited, of Manchester, England.

quantity of copper. Since these experiments, the Admiralty have never wavered in their practice of causing all their steel plates to be "pickled" to remove the mill scale, as is done for galvanizing.

A fruitful cause of pitting and corrosion is the small particles of carbon and slag which get rolled into the surface of the plate during manufacture. These, when brought in contact with the salt water, readily cause pitting by galvanic action. It is quite usual to see the sides of steel steamers of the mercantile marine thickly covered with small rust spots and rust cones, as they are technically called. If these cones be carefully removed and examined, a little pit will be seen, containing a particle of black oxide, which, under a layer of paint, has been insidiously eating its way into the plate. This again shows the advantage of the pickling process, as under this process any such scale, slag or imbedded carbon is dissolved out.

With the discovery of the rapid corrosion of the hulls of steel steamships many antidotes were proposed, among them being the so-called protective and anti-corrosive paints. These paints are usually compounds of lead and zinc. Their action is extremely limited; at any rate they possess little value over ordinary paint when applied to plates covered with mill scale. The best practice appears to be to remove the scale by pickling the plates, and to thoroughly clean and dry all plates before putting on the paint, and this practice is carried out in the hull plates of all modern ironclads and mammoth steamships when built of steel.

Turning now to the boiler, we see that from the first hour the boiler is set to work, it is acted on by destroying forces, more or less uncontrollable in their work of deterioration. These forces may be distinguished as chemical, electrical and mechanical, sometimes acting independently, but often acting together, to bring about the destruction of the boiler by corrosion and wasting, which corrosion may be either external or internal.

External corrosion is almost exclusively due to oxidation, the causes of which may be exposure to the weather, presence of moisture and leakage of seams and rivets. And here it will be convenient to state that iron will not rust in pure dry air, in pure dry oxygen, or in pure dry carbon dioxide. Neither will it rust in pure distilled water, free from oxygen. But in moist air corrosion rapidly commences. Take the case of the bottom of a steamer's boiler, usually placed in close proximity to the bilges. The bilge water will be rich in carbon, due to the amount of coal dust in it, and the radiant heat from the bottom of the boiler evaporating this water, the evolved moisture will, together with the carbonic acid there formed, simultaneously attack the iron plate, if unprotected, and form a thin layer of ferrous carbonate. The ferrous carbonate so formed is at once oxidized by more oxygen and converted into ferric oxide. If plenty of moisture be present, ferric hydrate is formed. During these reactions the carbonic acid is liberated in the metal, and reacts with more oxygen from the air to carry on the process of destruction, which is now further accelerated by the fact that the hydrated oxide on the surface is electro-negative to the metal itself, and, excited by the presence of moisture and carbonic acid, creates a galvanic current at the expense of the metal, and, the rust being porous, the action continues until all the metal is destroyed.

Corrosion, like all other forms of chemical action, is much accelerated by increase of temperature, and, in the bottoms of ships and boilers, the boiler bearers and bunker plates in proximity to the boilers, this has a considerable effect in increasing the rapidity of rusting; also in coal bunkers the mere contact of moist coal with the iron plates sets up galvanic action, carbon being electro-negative to the metal.

Let us now refer to a simple laboratory experiment. If a strip of copper and a strip of zinc be taken and immersed in a bath of dilute sulphuric acid, both metals will be chemically acted upon and eaten away; but if we

connect them together by a wire, a remarkable change takes place, and a definite electrical current is set up, the copper being protected at the expense of the zinc, which is rapidly destroyed. Now, for the present, I simply wish to call attention to three facts : That to produce this chemical action we require (1) dissimilar metals, (2) an exciting medium, and (3) we notice that the electro-positive metal is destroyed. Now, the rusts or oxides of any metal being electo - negative to the metal itself, it requires only the presence of moisture and oxygen to produce electrical action, and the corresponding destruction of the plate. Thus we see that oxidation once begun, and a rust scale once formed, how in the presence of moisture galvanic action may take place and rapidly corrode the metal plate. This brings us to the question of the importance of keeping all boiler shells quite dry and protected from the action of the weather or moisture, and the necessity of keeping all rivets and seams tight and free from leakage. Especially is this the case with marine boilers using salt water, where the leakage will consist of a concentrated solution of brine, capable of forming a much more active exciting medium than fresh water, and as a natural consequence, the corrosion will be much more rapid.

If there be leakage in the presence of dissimilar metals, we should expect to find the destruction of one of them very rapid. Now, it is a common practice to place brass mountings and fittings in connection with the iron or steel shell plates of boilers. Should any leakage take place round the threads or flanges of any of these mountings, we have at once all the conditions of a voltaic cell, and it is common experience to find that where leakage has taken place as described, the destruction of the iron plate is sure and rapid. I have myself experienced much trouble from corrosive action and the leakage of ring seams and rivets, and also from leakage round the flanges of brass mountings, especially in the case of blow-off cocks, where the leakage is induced by the unequal expansion of the metals.

In the case of Lancashire and Cornish boilers the most rapid corrosion takes place in the flues, and adjacent to the brickwork setting. If the boiler be set in a mass of brickwork, the latter will retain and keep in contact with the boiler any moisture that may find its way to the plates. The gases in the flues will be rich in the products of carbon and sulphur, and these products, in the presence of moisture, will form a strongly exciting medium, and together with the oxide there formed, will rapidly corrode the plate.

Internal corrosion takes three forms —general wasting, pitting and grooving—and, as before, we can trace the cause to either chemical, electrical or mechanical action, sometimes acting singly, sometimes together to bring about the destruction of the boiler. Grooving is generally due to defective construction or the too rigid staying of the ends by gusset or other stays, which prevent expansion of the furnace tubes or other heated parts. It will be at once seen that there is an immense difference between the temperature of the top and the temperature of the bottom of a furnace tube, for the top is in close proximity to the heated gases, and the bottom, being covered with ashes, is comparatively cool. Hence, there is a tendency of the furnace tube to arch, and a springing action of the tube plate is required. If this is not provided for, an excessive stress is thrown upon the plates of the furnace tube, often greater than they were designed to bear, with the result that, after frequent repetition, and with the less ductile kinds of plate, cracking of the metal takes place, and if there be any acidity or corrosive agent in the water, it will at once attack the metal so bared, and widen the crack into a groove. Grooving generally occurs round the flanged ends of the furnace mouths and end plates of boilers.

General wasting and pitting are caused by chemical and electrical action. These actions may be induced by the lubricant used in the engine finding its way into the boiler ; air or oxygen dissolved in the water ; mill scale

carbon, or oxides of the metal being present; difference of temperature of the metals, and want of homogeneity in the metal.

With triple-expansion engines the majority of lubricants are at once vaporized in the high-pressure valve chest or cylinder, and pass with the steam into the condenser, there to be taken up with the feed water and pumped into the boiler. It is well known that animal or vegetable oils, when decomposed or oxidized, produce acids; hence animal or vegetable oils must never be used for internal lubrication of steam engines. None but the best mineral oils (pure hydrocarbons), having a high vaporizing point, should be used. Even with mineral oil after vaporization a change has taken place. If water be evaporated and condensed, it remains water; but if oil be evaporated and condensed in the presence of moisture, its nature is changed. True, it retains its greasy nature, but it has become oxidized, and on condensation will appear as a slimy emulsion.

Bad oils, there is no doubt, have frequently caused pitting wherever they have settled upon the heated parts, and, to prevent the introduction of oil into the boiler, many engineers have adopted the use of sponge or other feed water filters to extract or retain the oil from the feed water, while others have discontinued the use of internal lubricants altogether. Many of the Clyde and Tyne firms in Scotland are building engines in which no internal lubrication is used. I have seen triple-expansion engines of 5000 horse-power which have run for years without any injury, and whenever I have had opportunity I have removed or closed all internal lubricators, and have seen nothing but good effects follow. The oil is evaporated before it reaches the cylinder, and goes into the boiler in a condensed state, without having done any good to the engines. A great deal of trouble is caused by air, either dissolved or free, in the boiler. The troublesome matter is, of course, the oxygen in the air. This, forming oxides, is powerfully aided by the exciting saline constituents of sea water to produce galvanic action, and thus destroy the metal.

Special mention must be made of that kind of corrosion known as pitting. This pitting is occasioned by the same causes that induce general corrosion, but these are intensified by two other influences which render the corrosion local instead of general. The influences are rust, mill scale, or other impurity, and variation of temperature. Rust and iron scale are generally in the form of magnetic oxide of iron, and when the metal of the boiler is acted on chemically by the sea water, whilst in intimate contact with this oxide, the oxide and the metal in its immediate vicinity constitute a voltaic couple. The metallic iron or steel, being the most readily acted on, becomes the corroded or positive element. This couple induces a current of electricity, having only a very local influence, thus concentrating the action on that limited portion of the iron or steel which has become positive through the influence of the oxide or scale, instead of allowing that action to expend itself generally over a large area.

Variation of temperature affects more particularly the question of the very serious and dangerous pitting observable on the sides of furnace tubes. In cases where two portions of even the same plate of iron or steel are subject to unequal temperatures when immersed in a liquid capable of chemically acting on them, these two portions become virtually two different metals so far as molecular arrangement is concerned, and are capable of forming a voltaic couple. The more highly heated portion, being the most readily acted on by the sea water, becomes the positive or corroded element, while the less highly heated portion, being the less liable to chemical action, is the negative element. Thus, when through any physical or structural causes one part of the metal becomes more highly heated than another part, such as the sides of the furnaces at the line of fire-bars and parts of the combustion chamber, this more highly heated part becomes positive to the less highly heated

parts, and concentrates on itself all the corroding or chemical action which would have diffused itself generally had the temperature been equal.

Referring to our voltaic cell, it would appear that there are three ways in which we can prevent corrosion of our copper strip—(1) by not immersing it in a corrosive fluid; (2) by introducing into the corrosive fluid and connecting to it a more readily acted on metal, zinc, for instance; and (3) by rendering the fluid non-exciting. Now, engineers have endeavored to preserve the life of boilers by one or other of these methods. Under our first condition we must have a non-corrosive fluid, and the only way to obtain this is to use perfectly fresh pure water, all losses and leakage being made up with fresh pure water. In the case of marine boilers an "evaporator" must be used to supply pure water, and so prevent the use of the sea for making up the feed; secondly, we can place slabs or blocks of zinc in connection with the iron, so as to preserve the iron at the expense of the zinc; thirdly, we can render the sea water innocuous either by removing the salts or by introducing a chemical substance to counteract their influence. I propose just briefly to consider and compare the last two methods of prevention.

If zinc be used in sufficient quantities, and be properly applied and connected to the boiler, the protection afforded from corrosion is perfect, whether from the water itself, galvanic action due to any cause, or air admitted with the feed. This result is given to us by both experience and experiment, and is universally admitted and carried out in practice. If there be no metallic contact, then the action of the zinc becomes analogous to our last condition, that of rendering the water non-exciting. Many compounds are placed upon the market which profess to neutralize the action of the saline constituents of the water; but it will be evident from what has gone before that the best will be one which contains a readily soluble basic compound of zinc.

It would certainly seem that the most logical method of preventing corrosion is to make the water non-exciting, or incapable of acting chemically on the iron or steel of the boiler; thus the cause is at once attacked, while the other method deals with the effect. There is also avoidance of the great difficulty of making and maintaining the metallic contacts owing to corrosion at the points of juncture, and the breakage of contact through other causes. Such imperfections can only be remedied when the boilers are opened. The great advantage in the use of such anti-corrosive compounds is that they can be introduced in small quantities at stated intervals. They should be added to the feed water, either at the condenser or hot well, from time to time, in greater or less quantities as desired. Care should be taken not to put into the boiler any compound either itself capable of combining with iron or of forming compounds capable of so combining, but it should be a *sine qua non* that the protective agent should be itself harmless. But marine engineers view all these compositions with a suspicious eye, and, not understanding their reactions, prefer to use the zinc plates, and introduce soda in small quantities at regular intervals at the hot well. This is the now almost universal practice in the navy and merchant service.

Merely placing the zinc in trays, hangers or straps will not ensure metallic contact, and the action of the zinc to prevent corrosion under the circumstances will be limited and weak. Many sea-going engineers profess not to believe in the metallic contact, and merely throw half a dozen slabs or so of zinc into the bottom of the boiler, while others hang them from the stays on hooks, somewhat like meat hanging in a butcher's shop. The folly of this course can be best shown by citing some experiments made by Mr. D. Phillips, and embodied in a paper which he read before the Institute of Civil Engineers in 1885. I give this in Mr. Phillips' own words. He says: "I wish to draw attention to a small laboratory experiment I carried out, in which

surfaces of bright pieces of plate iron immersed in cold sea water for over ten years have been thoroughly preserved from corrosion with the aid of pieces of zinc in metallic contact, whilst a similar piece similarly fitted and immersed, but having a piece of paper between the zinc and the iron, received no protection. The water was changed twice annually, and the oxide removed from the zinc by filing. Under these conditions the iron became gradually coated with a film of lead-color deposit when wet, but hard and white when dry. The effect in other respects was that on every occasion that the oxide and deposit were removed from the zinc and iron specimens, on being returned to the water small globules formed on the zinc, and on reaching $\frac{1}{10}$ inch diameter released themselves and flew to the surface. What takes place between the zinc and the iron of boilers at high temperatures, with the water boiling and circulating, I am not prepared to say, further than that the latter can be, and is, preserved from corrosion by the former if properly applied."

Now, there are two ways of applying our zinc so as to secure the desired metallic contact. One method is to fix it by soldering conducting wires leading from the iron of the boilers to the zinc slab. This method is now discarded, for the reason that there is not sufficient surface and distribution of the points of contact; also that it is almost impossible, when cleaning out the boiler, to avoid entangling wires and breaking the points of contact. The better and generally recognized method of fixing is to place a number of studs into the sides of furnaces and combustion chambers, and to bolt on to these studs the zinc slabs, which should be about 10 inches by 6 inches by 1 inch. It is important to see that the contact surfaces are clean and smooth, and that the nut is screwed up tight to exclude the water. When so applied the protection against corrosion is perfect. The proportions necessary to ensure complete protection are 1 square foot of zinc to 50 square feet of heating surface in new boilers, which may be diminished after a time to 1 to 75, or even 1 to 100.

In conclusion, I would draw attention to the chief points which should be attended to by those who have charge of steamships or steam boilers.

As to the hull.—If of iron, see that all blisters and rust are removed by chipping; and if of steel, the magnetic oxide or mill scale should have been removed before applying the paint. Use paint of a good quality; one that consists of a compound of zinc or lead will be best, because it will be more readily oxidized. See that the surfaces are thoroughly dry before painting, as it is quite usual to see paint put upon ships' hulls when wet.

As to the boiler (externally).—1. Keep all seams, joints and rivets tight and free from leakage. 2. Prevent, as far as possible, all moisture getting into contact with the plates. 3. At least once a year apply a coat of good paint; red lead and linseed oil being the best for this purpose. (Internally.)—Firstly, select a good cylinder oil where it is impossible to work without one, and only use such oils as have a vaporizing point at a higher temperature than the temperature of the steam at the pressure at which the boiler is to be worked. Do not take the statement given of the vaporizing points of these oils for granted, even though it may be a standard brand or make, but see that each particular lot as supplied is equal to the sample which influenced the purchase, as it may be taken for granted that the lowest quality that will be accepted without complaint will be about the highest quality supplied. Under any condition endeavor to keep your boiler water as fresh as possible, and where a fresh water supply cannot be obtained, it is desirable to fix some contrivance, such as an evaporator, to obtain the same; and, lastly, if it is impossible to dispense with the use of sea water, means must be taken to counteract its evil effects, such as those I have endeavored to show in this paper.

Under these conditions we should be rewarded by our boilers not being cut off in their prime, but dying of old age.

# PRESSURE GAUGES.*

*By C. R. L. Lemkes.*

IT was in 1844 when a Frenchman, Vidi, invented what is to-day known as the aneroid barometer, the principle of which has been adhered to in the construction of all metallic pressure gauges down to the present day. Vidi's pressure gauge, or barometer, consisted of a closed vessel with elastic walls, which are pressed in, more or less, according to the relative pressures inside and out.

The tube gauge, or barometer, embodying the principle of the well-known Bourdon tube, was first constructed in 1845 by a German, Schinz, and was made for him by a mechanic, Rosekapp, of Coblentz-on-the-Rhine. Five years later, in 1850, M. Bourdon patented this idea, and in 1859 the French courts held that Bourdon's patent had been anticipated by Vidi, because Vidi's patent referred to "any form of closed vessel with elastic walls," and the Bourdon tube was held to be included in this. Bourdon was, therefore, ordered to pay an indemnity to Vidi. It may be mentioned that in Germany the Bourdon gauge is to this day known under the name of Schinz. The Schäffer gauge was patented in 1849—one year anterior to Bourdon's patent, and was the first steam gauge, as neither Vidi nor Schinz ever contemplated using their instruments for any purpose other than the measurement of barometric pressures.

The simplest form of pressure gauge is the open mercurial column, in which the pressure to be measured is balanced against a column of mercury. This apparatus usually consists of a closed iron reservoir, partly filled with mercury, upon the surface of which presses the air or other fluid whose pressure is to be measured. The ascending tube is made of glass, say, in six-foot lengths, joined together by means of iron stuffing boxes, and fitted with a boxwood scale, the upper end of the tube being left open to the atmosphere.

A column to indicate up to 300 lbs. per square inch, requires a vertical height of 51 feet, and in any tall building some wall with a clear flight can usually be found where this can be erected, the column passing through various floors if necessary. The whole length of the column should be fitted with ladders or other convenient means of access, and a speaking tube, with various flexible tube branches, may be employed for communicating the readings to the observer. The pressure is obtained by means of a hand pump, the medium being preferably air, which is cleaner to work with than water, and precludes the possibility of any error due to a column of water on the mercury.

In graduating the mercury column, due allowance must be made for the fall of the level of mercury in the reservoir as the mercury ascends the tube, and, to effect this accurately, it is advantageous to fit the reservoir with a level indicator, similar to a small iron water gauge. The fall of the mercury in the reservoir depends upon the relative areas of the bore of the glass tube and

* Revised extract from a paper read before the Institution of Engineers and Shipbuilders in Scotland.

C. R. L. Lemkes has for many years been connected with one of the largest firms of pressure gauge makers in the world, and in the above paper has given some of the more interesting experiences acquired in that time. He was first engaged at the home works in Germany of Messrs. Schäffer & Budenberg, and subsequently was appointed their representative in Scotland and Ireland.

the horizontal section of the reservoir, and it can be reduced to a minimum by the use of a very shallow reservoir of large area, and a glass tube of fine bore.

If a mercury column is fixed so as to be subject to material changes of temperature, an allowance must be made for the error due to the expansion of the mercury. On a column 50 feet long, corresponding to a pressure of 295 lbs. per square inch, the variation between the freezing point and 70 degrees F. will amount to 4.32 inches of mercury, which is equivalent to a pressure of 2.10 lbs.

The tube of a mercury column, as well as the mercury itself, must be kept scrupulously clean. Unless this be done, the mercury will cling to the sides of the tube, thereby interfering seriously with the reading of the instrument. The glass tubes must, therefore, be cleaned from time to time, and this is best done by drawing a piece of cotton wool through them by means of a cord. Metallic wires, especially steel wires, should never be used for this purpose, as the slightest pressure against the inner side of the glass will produce a scratch sufficient to cause early fracture.

It may be interesting here to enumerate the standards to which the mercury column is graduated for the various measures of pressure. At a temperature of 60 degrees F. the height of the mercury column is 2.035 inches for every pound per square inch—which is nearly 17 feet for 100 lbs. per square inch. The English atmosphere is accepted as equivalent to a mercury column of 29.9 inches, and this corresponds to a pressure of 14.7 lbs. per square inch. This standard is in use in Great Britain, the United States, Russia, Italy, Belgium, Holland, Sweden, Norway, Spain, Portugal, and Switzerland. On the other hand, in France, Germany and Austria, pressures are usually expressed in terms of atmospheres, the standard being one atmosphere, which equals one kilogr. per square cent. or a mercury column of 735 mm., or 28.94 inches. The French atmosphere, accordingly, corresponds to a pressure of 14 22 lbs. per square inch, as against 14.7 lbs. per square inch for the English atmosphere, and in making a comparison of pressures upon the standards care must be taken that these values of atmospheres are not confounded.

It should be borne in mind that the pressure indicated by the mercurial column—and the same remark applies to all types of gauges ordinarily used—is simply the amount by which the pressure exceeds that of the atmosphere, and this is evidently a variable quantity for the same absolute pressure, inasmuch as the pressure of the atmosphere varies at different times. Thus, when we speak of 30 lbs. per square inch, we mean the pressure exceeding the pressure of the atmosphere, for the time being, by 30 lbs., and the absolute amount of this pressure will vary with the pressure of the atmosphere.

For practical use, the mercury column has been almost entirely superseded, excepting for very low pressures, by the various forms of metallic spring pressure gauges. Many varieties of these have been invented, but the principle underlying them all is that of giving indications depending upon changes of form in a vessel affected by the pressure which is to be measured. The only types of pressure gauges that have permanently held the field are those named after Bourdon and Schäffer.

The Shäffer gauge, as already stated, was patented in 1849 by the late Mr. B. Schäffer. The action of this gauge, shown in Fig. 1, depends upon a corrugated steel diaphragm A, firmly held between two flanges, B, and to the underside of which the pressure is applied. The movement of the diaphragm is communicated by means of a rod, C, fitted with a neat little ball joint, D, to a small block, E, held by two small screws, F, in a toothed quadrant, G, gearing with a pinion, H, which carries the pointer indicating on the dial.

This mechanism serves to multiply the movement of the diaphragm in such a way that a very slight movement is shown on a greatly enlarged scale by the pointer on the dial. A spiral spring

of copper, J, is provided on the pinion to take up the slight amount of "play" which is unavoidable between the pinion and quadrant. A very thin protecting plate of silver or silvered copper is placed beneath the steel diaphragm to protect the latter against corrosion. For certain chemical purposes, where

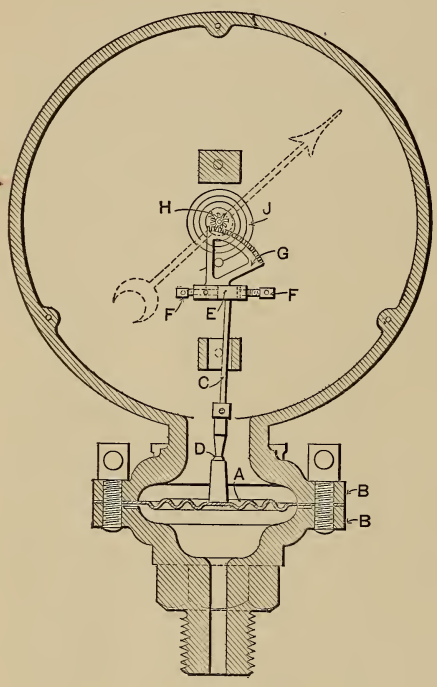



FIG. I.—THE SCHAFFER GAUGE.

acid substances enter the gauge—as, for example, in pulp digestors—the protecting plate is made of platinum. The corrugated diaphragm is stamped out of the sheet, and is, of course, hardened and tempered. These operations require experience and skill. When completed, each diaphragm is subjected to a series of exhaustive tests under both steam and water, in order to detect any possible defects, and to ensure that it has an ample margin of elasticity under the pressure for which it is intended.

In a Schäffer gauge, with a 6-inch dial, graduated to 200 lbs., and intended for a working pressure of 100 lbs., the diameter of the free part of the diaphragm, that is, the part that moves, is 2½ inches, and the total range of movement of the centre of the diaphragm is ⅛ inch, which movement is multiplied about 80 times on the dial. The limit of elasticity of such a diaphragm must exceed 300 lbs. per square inch, which is 300 per cent. in excess of the working pressure of the diaphragm. Each gauge is graduated, point for point, by comparison with two large standard test gauges, which must check one another. The Schäffer gauge is manufactured graduated to any pressure up to 400 lbs. per square inch, and may be used for any working pressure up to 300 lbs.

In the Bourdon gauge, Fig. 2, the essential part consists of a brass or copper tube, K, of elliptical section, bent in the form of a circle, one end of the tube being soldered into a boss, L, by which the steam or other fluid under pressure is admitted, whilst the other end is closed by a cap or plug, M, and is left free to move. When the press-

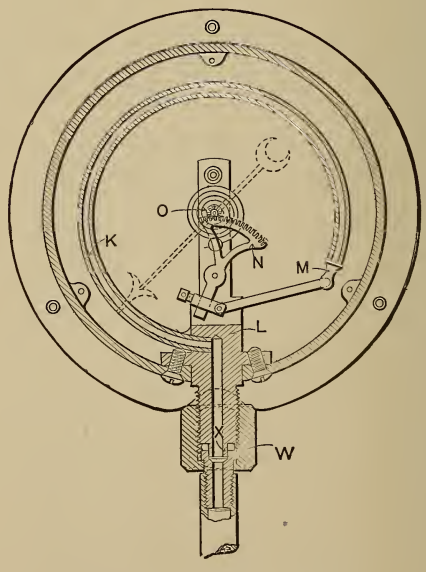



FIG. 2.—THE BOURDON GAUGE.

ure is admitted to such a tube, the elliptical section has a tendency to change to the circular form, and, in consequence, the tube tends to straighten, and the free extremity of

the tube moves away from the end fixed to the boss. In the case of gauges with eccentric hand, this movement is communicated direct to a small crank on the spindle of the pointer, and this constitutes at once the simplest and most durable arrangement.

In the ordinary gauge with concentric hand, the movement of the tube is multiplied and communicated to the pointer by a toothed quadrant, N, and pinion, O, in a manner closely resembling the arrangement employed in the Schäffer gauge. The works are preferably fitted to the boss carrying the tube, and not to the back of the case, so as to render the works of the gauge quite independent of the case. If the works are fastened to the back of the case, the strain on the gauge case—even such as might be produced by tightening, more or less, the screws by which the case is attached to the boss—may produce variations in the indication of the gauge. The arrangement of carrying the works on the boss has the further advantage of allowing the use of a loose back, secured by screws, for obtaining ready access to the interior of the gauge ; whilst the other alternative of retaining the loose back, and fixing the works behind the dial, is decidedly objectionable. All parts of the mechanism must be fitted up in the nicest possible manner so as to ensure perfect freedom of movement in the various joints and bearings, without the slightest play in the direction of movement.

The Bourdon tubes are frequently made of solid drawn tubes of brass or composition metal. The quadrants in these gauges are made of steel or of a hard brass, gearing in steel pinions ; and latterly pinions of German silver have been introduced, gearing in quadrants of steel or hard brass. In gauges intended to work under severe vibration,—on traction engines, for instance, —pinions of steel are employed, working in bearings bushed with nickel. The range of pressures within which Bourdon gauges are made is practically the same as for Schäffer gauges.

The steel tube gauge, Fig. 3, works upon the same principle as the Bourdon gauge, and differs from the latter mainly in having a tube, P, made of steel instead of brass, the other differences being merely points of detail. Some makers employ solid drawn steel tubes, but these are vastly inferior to the tubes turned out of solid steel—provided a suitable material is selected, and the tubes are accurately made and correctly tempered. The tubes in all these gauges, manufactured by Messrs. Schäffer & Budenberg, are bored and turned out of a special brand of Shef-

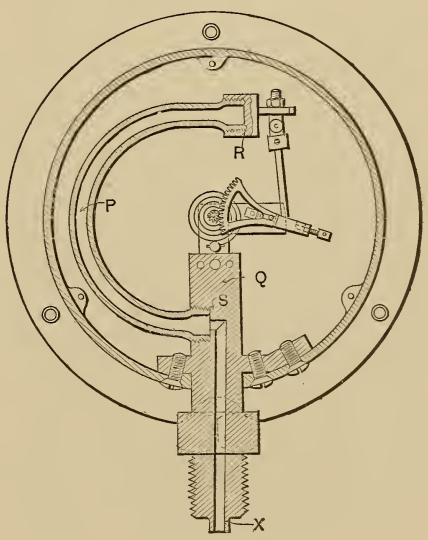



FIG. 3.—A STEEL TUBE GAUGE,

field pressed steel, the tubes being made of a large variety of shapes and strengths, according to the pressures for which they are intended. The tubes are bored after the manner of boring the barrel of a gun, and are then turned up on a mandril. They are highly polished, both inside and out, to remove every trace of tool marks, and are afterwards microscopically examined by light reflected from a mirror, any tube showing the slightest flaws or scratches being rejected as unfit for use.

The tubes are then carefully bent and flattened at a moderate heat, and are next hardened and tempered, operations which again require much ex-

perience and skill. The ends of the tube are screwed into the boss Q and cap R, respectively, and a metallic joint is made at each end by a turned edge, S, bedding into the softer material of the boss and cap. The dial in each gauge is, of course, graduated to its own tube.

For hydraulic work, steel tube gauges are made for pressures up to 10 tons on the square inch, and they have been in some cases constructed with graduations up to 30 tons per square inch. On the other hand, steel tube gauges are also made regularly for ordinary steam pressures, and, by way of experiment, even vacuum gauges with steel tubes have been successfully turned out. The gauges are graduated and tested under pressure of oil, and the oil left behind in the tube, together with the incrustation formed in the operation of tempering, afford protection against internal corrosion of the tube; but, as an additional safeguard, the tubes may be tinned. In gauges for marine use, the tubes are usually tinned both inside and out, to protect them against the corrosive action of the sea air. For low pressures the steel tube gauge has little or no advantage over the Schäffer or Bourdon, and therefore the latter have the preference, being lower in price; but for the high pressures of steam, now so common in land as well as marine practice, it has the decided advantage over the older types as regards accuracy, reliability and durability, which is greatly due to the more perfect elasticity of steel as against brass.

For standardizing hydraulic and other gauges for high pressures, it is necessary to resort to some means other than the mercury column, as it is, generally speaking, impracticable to carry the mercury column beyond about 500 lbs. per square inch, which, itself, requires a vertical height of 85 feet. For higher pressures, special hydraulic testing machines, in which the pressure is applied by dead-weight, are employed, and much ingenuity is displayed in the arrangement of various devices for reducing to a minimum the errors due to friction and other causes. The readings of these machines can be checked to the greatest nicety by comparison with a mercury column up to, say, 500 lbs. A few years ago, however, a mercurial column of enormous height, and indicating up to 350 atmospheres, or 5145 lbs. per square inch, was fixed to the Eiffel Tower, at Paris, and this afforded the first opportunity of testing practically, and with absolute reliability, to this enormous pressure.

When a gauge becomes inaccurate, the only satisfactory way of restoring accuracy consists in re-dividing the scale, but as this cannot well be done by the user, it becomes convenient to provide means of adjustment in the mechanism of the gauge, whereby any ordinary mechanic can approximately correct any errors. The errors in the indication of a gauge may be two-fold, viz., first, those equivalent to a simple displacement of the pointer,—for example, when the pointer indicates 2 lbs. too high all round the scale; and, second, errors which increase in proportion to the pressure, being, say, 2 lbs. at 20, 4 lbs. at 40, and so on, these being generally a sign of weakening of the tube. The former error can, of course, be corrected by altering the position of the pointer on the spindle, or, better still, by making the connecting rod, attached to the end of the tube, in two pieces, fastened together by means of screws, in such a manner that the length of the rod can be adjusted. The second class of errors can be corrected by altering the ratio of multiplication of the mechanism, and means for doing this can be provided by making an adjustment where the connecting rod is attached to the quadrant lever.

The pointer is secured by driving it on to the spindle, being usually held by friction, and the spindle is either made square or conical, and slightly tapered. The square spindle has the advantage of greater security for the pointer, but the exact position of the pointer cannot be so readily varied as with a round, conical spindle. The pointer should be

perfectly balanced. A stop, or rest pin, is provided behind the counter, in such a position as to throw the mechanism under a slight strain when the gauge is disconnected. This serves to protect the gauge against damage in cases of slight shocks. The dial of the gauge is preferably made of tin, covered with a thick coat of enamel, which will neither crack, blister nor discolour under heat.

Since the indications of a pressure gauge vary with the temperature of the instrument, it follows that all gauges, when in use, should be kept under the same conditions, as regards temperature, as when they were graduated. When a gauge is fixed on a boiler it is liable to heating in two ways,—first, owing to direct communication between the steam space and the spring of the gauge; and, second, owing to the surroundings of the gauge,—that is, the heat radiated by the boiler, or otherwise conducted to the gauge, for example, through the fitting which carries the instrument.

When steam is admitted to the tube of a Bourdon gauge, the increase of temperature will cause the tube to expand, and, as the heating is confined to the tube, an error will result in the indication of the pointer, corresponding to the movement of the end of the tube. Similarly, in a Schäffer gauge, the direct admission of steam beneath the diaphragm will affect the indication of the gauge, owing to the difference of expansion of the steel diaphragm and the iron casing. But apart from the errors thus produced, the continuous heating of the tube, or diaphragm, in this way has an effect on the elasticity of the spring, and rapidly deteriorates the accuracy of the gauge. It is, therefore, essential that the pressure of steam should be communicated to the spring through a cool medium, and for this purpose a water syphon is employed.

Regarding the general heating of gauges, it may be noted that if the metals employed in the construction of the gauge and mechanism had the same coefficient of expansion throughout, a uniform increase of temperature of the whole gauge would not produce any differences in the relative position of the tube and the works, and the indication of the pointer would not, therefore, be affected. In practice, however, it is not possible to make these parts of the same metal, and, hence, the general heating of a gauge has an actual effect on the indication, the action being similar to that on which the principle of the pyrometer is based. As a rule, it may be taken that serious discrepancies from this cause are avoided if the outside of the gauge, when firmly touched by the hand, feels no more than comfortably warm.

The simplest form of syphon is formed by connecting the gauge with the boiler, by means of an ordinary wrought iron "U" tube. Upon locomotives a very simple and effective syphon is sometimes formed by the use of a copper tube, which is coiled round the gauge itself. Another very neat, though more costly plan, consists in utilizing the tube itself in the Bourdon gauge as part of a syphon. This is done by suspending the tube from the inner boss arranged in the topmost part of the case; the pressure is admitted at the bottom through a separate boss, and the two bosses are connected by a tube passing round the inside of the case. Arranged in this way, the water in the gauge tube cannot run out, and the gauge practically forms its own syphon.

The modern craze, however, for heavy and showy boiler mountings has led to the replacement of these simple, yet neat and effective, arrangements, by the pendant and other heavy brass syphons. These consist essentially of a large pendant tube, Fig. 4, closed at the bottom, and connected at the top with the boiler. Water collects in this tube, or bag, and another U tube, connecting with the gauge, dips into this water, the pressure being thus communicated to the gauge through the water in the pendant. This arrangement is satisfactory as a syphon, but compared with the plain wrought iron tube syphon, it has the disadvantage of forming a splendid conductor of heat

from the boiler to the gauge, which, especially at high pressure, tends to produce inaccuracies in the indication of the gauge.

It is customary to fit every pressure gauge with a cock for turning off pressure, to enable the user to disconnect the gauge at any time whilst the boiler is under steam. This practice opens up the danger of damaging gauges by the too sudden admission of pressure. In opening the cocks, if a water pressure, say, of 50 lbs. is admitted suddenly to a gauge graduated to 100 lbs., the pointer will jump far beyond the end of the scale, and the gauge is thrown out of order. Many gauges are ruined daily in this way, the blame being usually assigned to a defect in the gauge, rather than to the ignorance or carelessness of the operator.

Wherever sudden changes of pressure are unavoidable, as in many kinds of hydraulic machinery, it is advisable to fit the inlet to the gauge with a pressure check, consisting usually of a small

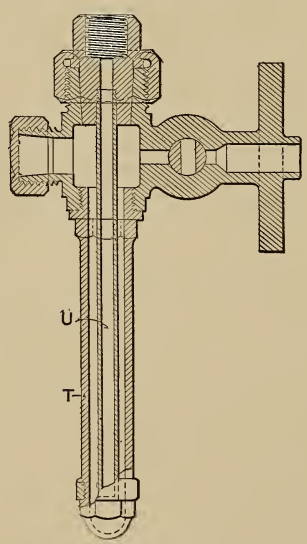



FIG. 4.—A PILLAR SYPHON.

loose valve V, Fig. 5, having a minute passage to serve as a bye-pass. Another form of check valve consists of a small screw, let into the connection of a gauge in such a manner that the end of the screw forms a valve against the inlet to the gauge. By adjusting this screw the passage can be reduced to any desired extent, and the whole can be readily removed for cleaning, if the small passage be made up by an obstruction in any way. To effect an adjustment of this screw, the gauge must be removed from its work; but this can be avoided by the use of a special screw-down valve with very fine thread, which will work in the same way, but is, of course, much more costly. For use in connection with air, oxygen or other gas, a very convenient form of check has been patented by Mr. W. M. Jackson, of Manchester, consisting of a series of alternate layers of copper gauze and felt, inserted in the connection of the gauge, and secured together by means of a screw. In the application of this check to gauges for oxygen bottles,—such as are used in connection with the limelight,—the primary object of the check is to prevent the sudden admission of pressure, which, in consequence of the compression of the gas in the gauge connection, might set free sufficient heat to produce an explosion if oil or other combustible matter should be present at the end of the tube.

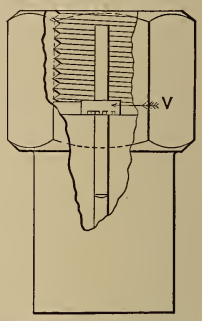



FIG. 5.—A HYDRAULIC NUT.

Defective joints in the connection are also a frequent cause of inaccurate registration of pressure gauges, owing to the connection being partly or wholly made up by the material used for making the joint. In many cases of this kind, the obstruction in the connection acts like a reducing valve, the gauge being thereby caused to indicate in the most erratic manner; and this is particularly misleading, as there is frequently no outward indication of anything being wrong with the gauge. For ordinary steam gauges, the joint is usually made with a lead or leather washer, W, Fig. 2; and there is no risk of the

connection being closed up by this washer if the bottom of the gauge connection is provided with a small projection, X, fitting accurately into a central recess or hole in the union, so as to prevent the washer from gaining access to the passage of the gauge.

In many cases, gauges are also found to be inaccurate in consequence of the gauge being subject to an initial column of water, as when a gauge is fixed at a lower level than the point where the connecting point enters the boiler, the pipe thus becoming filled with water. The importance of this point will be realized when it is borne in mind that, roughly speaking, every 2 feet height of water will make a difference of 1 lb. per square inch in the indication of the pressure gauge.

The accuracy of a pressure gauge, when correctly fixed, depends upon, first, the perfect elasticity of the spring within the pressure limits of working; second, the nicety and accuracy of workmanship of the works; and third, the accuracy with which the scale is graduated to the standard; and if these conditions are complied with as nearly as possible, and the gauge is treated with reasonable care, there is no reason why it should not remain perfectly accurate for many years. It has, however, become a matter of frequent remark that few gauges remain accurate after being in use for a considerable time. The chief reason for this is (apart from improper usages already referred to) that the springs are so frequently worked beyond their elastic limit, or, to put it another way, the margin of elasticity of the spring of the gauge is not sufficient beyond the pressure at which the spring is ordinarily engaged.

The safe limit of working pressure depends upon the material employed for the spring, and also upon the spring being proportioned in the most advantageous manner for the particular pressure, as determined on theoretical grounds by experiment and experience. For a working pressure of, say, 100 lbs., a gauge graduated to 200 lbs. should be employed. A gauge of this kind should safely stand a temporary pressure of 300 lbs. without exceeding the elastic limit; that is, when the pressure is released, the pointer should return exactly to the starting point. But if such a gauge were permanently worked to, say, 180 lbs., it will, sooner or later, give way, the application for a long time of, say, 180 lbs. having apparently the same effect on the elasticity of the spring as the temporary overpressure to double that pressure. A gauge of this kind should, however, remain perfectly accurate for many years if it is never engaged above 100 lbs. per square inch. By allowing a still larger margin in the graduation of a gauge, perfect accuracy can be still further ensured, but this is done at the expense of length of the scale.

Test gauges are preferably made in the form of duplex gauges, consisting of two complete gauge-works fitted in one case, and having two pointers to indicate upon the same dial, each gauge forming a check against the other. The eccentric type of gauge-works is the most suitable for test gauges, being simpler and less liable to get out of order than the concentric type.

On the European continent users of boilers are compelled, by law, to fit every boiler with a special flange, or other connection, for the application of an inspector's test gauge, the form of the connection being prescribed by the Government of each country. The gauge cock is usually made three-way, with a lateral branch, screwed or made with a flange to receive the control gauge. In Germany, an oval control flange of special dimensions is prescribed; a round flange, 30 mm. in diameter, is used in Belgium; 37 mm. in Bavaria; and a similar flange, 40 mm. in diameter, for France, Italy and Switzerland. For Austria, the control-gauge attachment must be made to receive a test gauge screwed to ¾-inch Whitworth.

In England, comparatively few boilers are provided with any special connection for the application of a test gauge, and the only means of checking the pressure consists in removing the working gauge and applying the test gauge in

its place—an arrangement which is altogether unsatisfactory. Many boilers, again, are fitted with connections to receive test gauges, but there is no uniformity in the connections employed; and not only do various insurance companies prescribe different connections, but even in the various branches of H. M. service different standards are in use. I do not propose that we, in England, should follow the example of our Continental friends, and compel the use of a particular type of connection on every boiler, nor does the difficulty call for so drastic a measure; but I do think that a great advantage would accrue from the adoption by common consent of a certain form of testing connection. The conversion of existing connections to such standard could be accomplished without difficulty by fitting a suitable intermediate connection.

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# THE AMERICAN BEET SUGAR INDUSTRY.

*By H. S. Adams.*

A NEW star has arisen in the industrial firmament of the United States. It shines in the Western sky with no uncertain light and promises to rival in brilliancy and intensity of glow its proudest neighbors. First coming into view some thirty years ago, it twinkled faintly and then passed away—apparently forever; but it reappeared more radiant than before, and its steady and ever-increasing power warrant the belief that it has come to stay. It bears no name stolen from the mythology of the ancients; no heathen deity stood sponsor for it; it goes by a most homely and common-place appellation—the sugar beet.

It is a stranger to most of us—this new factor in domestic agriculture—and comes to us, unfortunately, under the cloud of misunderstanding, for many still imagine beet sugar to be an inferior article—a substitute for the genuine thing. But this delusion will soon be cleared away. The modest plant has buried its root deep in the American soil and responds with a firm and determined yes to the query, Shall the United States produce its own sugar?

H. S. ADAMS was graduated at the Hartford, Conn., Public High School in 1882, and after several years of business life in New York connected himself with the beet sugar industry in Nebraska. Of this he has written to some extent in several periodicals, having had every opportunity to familiarize himself with its details and possibilities.

To those who associate sugar only with the succulent cane, this seems a very foolish question, for it is well known that it is a sub-tropical plant, and that on this account the area given up to its cultivation in the United States must always be restricted to a few States. Were it the sole source of marketable sugar, America must, therefore, of necessity, look to other countries for its main supply. The fact of the matter is, however, that for several years about sixty per cent. of the world's sugar supply has been contributed by the sugar-beet, thus leaving only two-fifths to be divided up among cane and all other sugar-producing members of the vegetable kingdom. And yet we go on, day after day—most of us—imagining that we have never tasted beet sugar, for, of course, we would know it if we had.

How much we are deceiving ourselves in this respect would be a comparatively easy matter to determine, and even a little investigation would do much to present the subject in an entirely new light. If we would take the trouble to penetrate the open secrets of the great refineries, we would find

SILOS FOR STORING BEETS.

that these huge agglomerations of brick and mortar, swarming with sweating humanity like prodigious beehives, are no distinguishers of sugars. With them sugar is sugar as it is to the chemist and should be to the outside world, and their portals open no wider to the raw cane sugar of the South than to the beet sugar of the same grade that Europe pours in upon them. All goes into the same common receptacles and when the glittering crystals fall like snow into the barrels, Europe and America are one, and one brand covers their saccharine output. So much for this fallacy of the inferiority of beet sugar which has gained surprising credence throughout the United States. Crystallizable sugar, or cane sugar, as it is called chemically, is always the same, whether extracted from sugar cane, beets, maple trees, sorghum or anything else capable of producing it. It looks the same, tastes the same and is the same.

As has already been stated, the cane district in the United States is very limited in extent. On the other hand, competent authorities state that the sugar-beet belt is of vast proportions, its boundaries being Canada, the two oceans and the line which, in days we should like to forget, divided the North and the South. It is not improbable, even, that time will prove its adaptability to States still further South, the successful factory in Southern California clearly demonstrating that, in spite of all theories to the contrary, the industry can be established in a semi-tropical climate.

There are, at present, six factories in the United States manufacturing sugar from beets, one-half of which are located in California, two of the others being in Nebraska and one in Utah. A plant has also been located in Virginia, but has never been operated on the same scale as the others. The oldest of these factories is at Alvarado, Cal., and is operated by the Alameda Sugar Company. Next in order comes the plant of the Western Beet Sugar Company at Watsonville in the same State. In 1890 the Oxnard Beet Sugar Company added to the list their factory at Grand Island, Neb., and under the stimulus of the new bounty law which

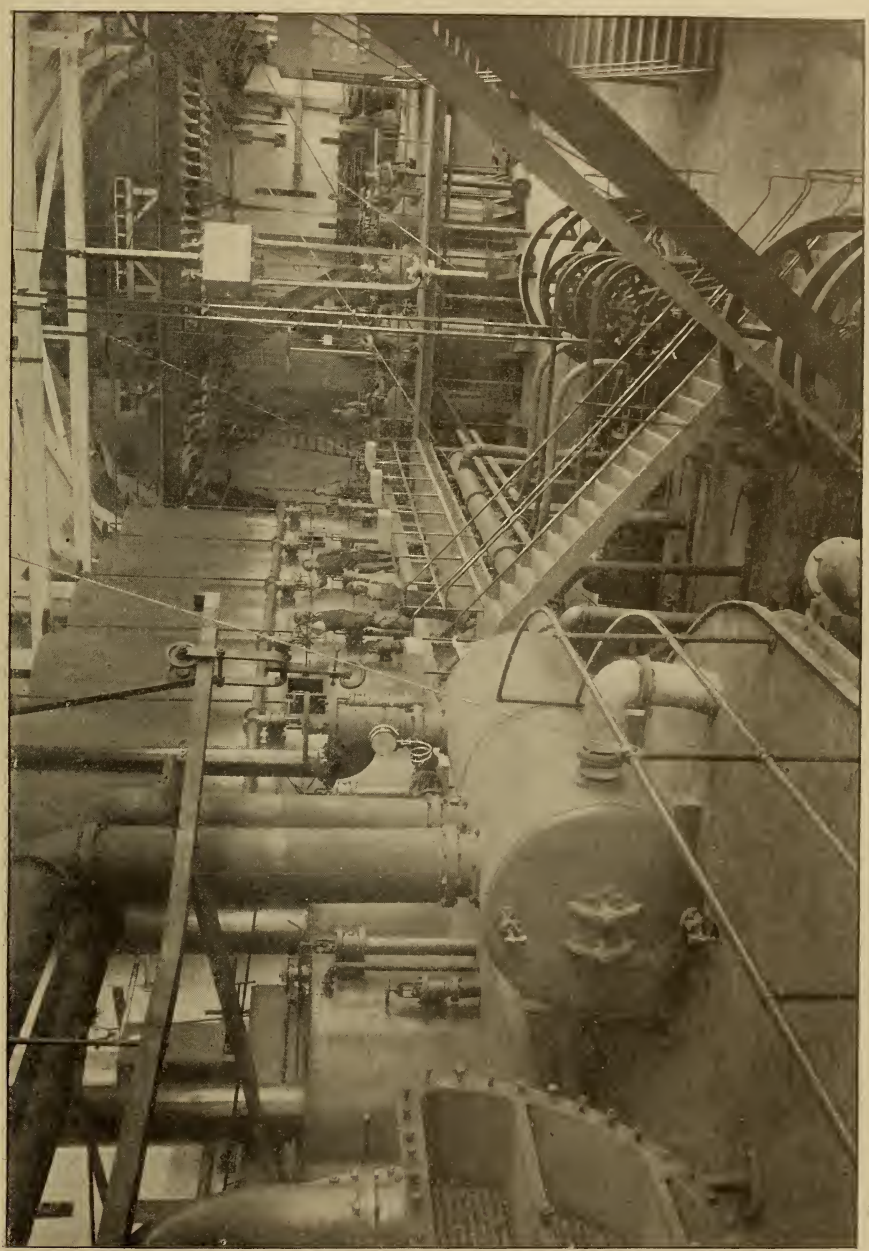
was approved on October 1 of the same year, three new plants were established in 1891, those of the Chino Valley Beet Sugar Company at Chino, Cal., the Norfolk Beet Sugar Company at Norfolk, Neb., and the Utah Sugar Company at Lehi, Utah. The largest of all these is the one at Watsonville, which has a capacity of about 1000 tons of beets every twenty-four hours. Second in capacity is the Chino factory, which consumes 800 tons during the same period, and was, last season, enlarged sufficiently to rival the champion in the northern part of the State. The

WAGON APPROACH TO A BEET SUGAR FACTORY.

others average about 350 tons, and though a comparison of figures makes them appear small, they are not in reality. It is only that the first two mentioned are particularly large, both having been increased from a much smaller capacity, the idea being to start in with a plant of fair proportions and enlarge it as the conditions should warrant it.

No one of these factories, however, was the pioneer of the industry in America. Its genesis, or rather, exodus, for it had to cross over from Europe, where it had gained a secure footing in France and Germany, took place in 1830, when a couple of Philadelphians tried their hands at it, but failed hopelessly. In 1838 it was undertaken again in the State of Massachusetts, at Northampton, though in too small a way to be successful. It is interesting to note, however, that the plan of drying the roots as the initial step of sugar extraction was attempted at this place, the idea being one that was then the subject of foreign experiments. After those failures, little interest seems to have been taken in a revival of the industry until a full quarter of a century had gone by. This time Chatsworth, in Illinois, was chosen as a location for the enterprise, and most unwisely, it seems, for the soil did not prove to be altogether adapted to the severe requirements of beet-culture, and lack of water, also, made successful operation impossible. Furthermore, the projectors had to contend with a lack of practical knowledge, as did their predecessors—a most serious drawback in the establishment of an industry of such complexity.

However, the factory struggled along for several years, but at length succumbed to the inevitable, and in the hope of retrieving their bad fortune the works were removed to Freeport in the same State, where a year's experience satisfied the persevering Germans that they had made another mistake. Later on, a part of the machinery was taken to Black Hawk, Wisconsin, but operations were again unsuccessful. Meanwhile experiments had been made at Fond-du-Lac, and, while hampered by



MAIN ROOM IN THE BEET SUGAR FACTORY AT GRAND ISLAND, NEB.

limited means financially, a foothold was gained, and sufficient prominence attained to attract the attention of capitalists, with the result that the plant was absorbed by a new company just organized at Alvarado, Cal. And thus, after traversing the entire American continent, the beet-sugar industry found a haven in the Golden State, and the foundation of one of its future sources of wealth was laid, for, though the final result was financial failure, the work was not all in vain, since it paved the way for the present factory at Alvarado and the one at Watsonville, both of which have been in successful operation for a number of years. So it is in Northern California that we find the industry first established with any degree of prosperity.

Its renaissance, so to speak, took place in 1890, when it was enacted by Congress that a bounty of two cents per pound should be paid by the government on all sugar of the required standard produced in the United States during the next fifteen years. As a further stimulus to the beet-sugar industry, then still in its infancy, though a not unpromising youngster, it was voted to admit duty-free all machinery imported for beet-sugar manufacture until July 1, 1891. On the strength of this law and faith in the fulfillment of the letter and spirit of it, four plants went up inside of two years, involving an outlay of over two million dollars. How stable these promises really were has been only too evident during the Congressional session of 1893–4, in which sugar was the great bone of contention, and which closed with a compromise on the question that was anything but favorable to the industry.

Every great movement has its leader —there is some one always who stands out conspicuously in the history of its progress, some figure whose presence at the head of the ranks is sufficient explanation for his being there. Such a man is Henry T. Oxnard, the president of one-half of the corporations operating in the United States, and also of the American Beet Sugar Association, who, in this new birth of the industry, is by far the most prominent figure. Indeed, he has been called the modern Napoleon of beet sugar, for he has been fighting for the United States the same battle that the great emperor did for France almost a century ago, when he took it upon himself to establish the industry among his people, thus creating for them a trust to be handed down to all posterity—a trust to which they have ever since clung with the utmost tenacity.

In the United States the establishment of the industry was a prodigious undertaking, a struggle of capital and brains to convince the Western farmer that a new era was dawning upon him if he would but awaken to its possibilities. How great that struggle has been none can realize but those who have been closely connected with it. It is not as if an industry had been created by which was opened up a new market for corn and wheat, their great staples, and they had simply to divert their product into a different channel; but here was a crop almost entirely unknown, and more than that—one whose introduction meant an entire revolution in agriculture. It was no easy matter to prevail on the farmer, used only to ride over his broad acres on a cultivator, to take up intensive farming and devote to a few acres as much time and energy as he had hitherto expended upon a large tract of land. He could not, or would not, see wherein lay the great advantage of concentrated effort and the gradual bringing up of the soil to a state of perfection. He knew full well that with corn and wheat he was at the mercy of the speculators, yet he hesitated to experiment with a new crop, partly, no doubt, for the very reason that it was new. But perseverance prevailed and the farmer, cautiously at first, tried the new crop, and as he found that while his labor had increased, his gains had grown larger also, and in greater proportion, his eyes were opened and half the battle was won.

Associated with Mr. Oxnard in the great campaign for the promulgation of this new industry have been his brother, James G. Oxnard, one of the best

FACTORY AND BEET SHEDS.

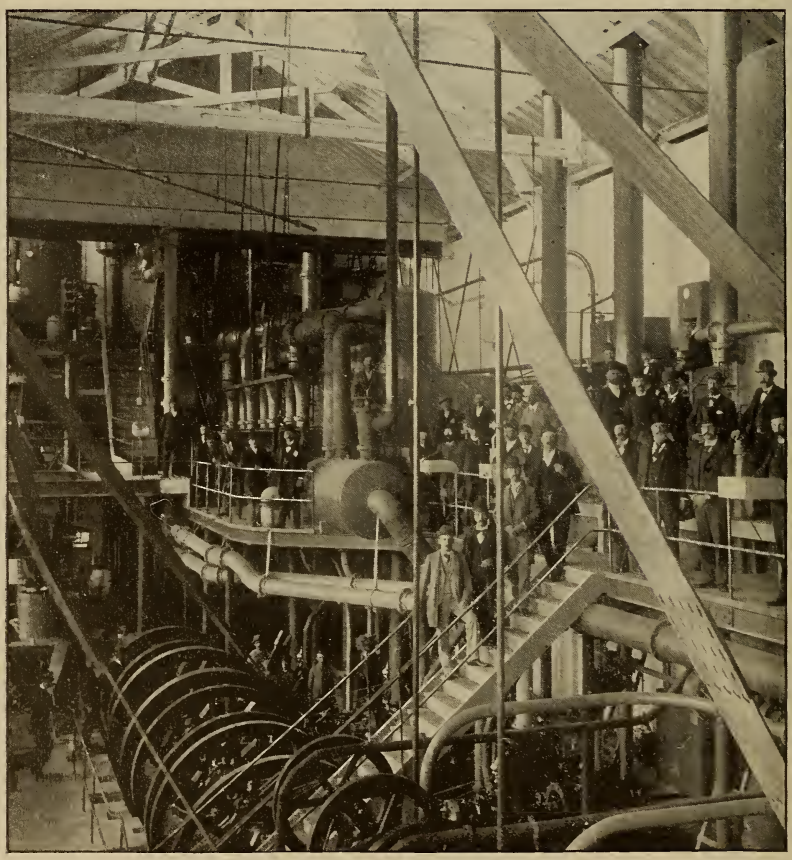
known sugar men in the United States, thoroughly posted in all the technicalities of the science of saccharine extraction. On him, therefore, devolved the adaptation of the intricate manufacture to American conditions. But before the beets could be converted into sugar they had to be grown, and many were the problems to be solved in this connection. This part of the work was left largely to James G. Hamilton, who devoted time and strength to furthering the cause agriculturally. Completing this quartet of pioneer workers is C. K. Hamilton, on whose shoulders fell the responsibility for the purchase of machinery and the erection of the three factories, as well as the arrangement of much of the detail work in connection with their organization for working purposes. With such an equipment success was half assured and the beet-sugar industry took a great stride forward.

Meanwhile the other three factories were steadily gaining ground, so that at the end of the campaign of 1893 things looked promising indeed, except for the cloud of impending legislation that hung gloomily over it. How far these forebodings were fulfilled is shown by the passage of the new American tariff bill last August, and the consequent abolition of the bounty after the lapse of one-fifth of the time that it was destined to be in force. What effect this will eventually have upon the industry can only be conjectured. It is a heavy blow, however.

The extent and character of the advantages occasioned by the establishment of a beet-sugar factory are many and varied; in fact, such a plant is unique among factories in general. It takes possession of a circle of territory whose diameter, in the present stage of the industry in the United States, is, perhaps, three hundred miles. This region it may be said to feed upon, yet back over the same area it distributes its product annually, thus ever returning what it gives, and, deriving, as it does, its entire sustenance, except fuel, from its immediate neighborhood, the community is not only benefited by the manufacture of the raw material, but by its production and the consumption of the finished article. Thus, its value as an industrial factor is far-reaching, and almost inestimable. There is another value, too, which might almost be called a moral advantage, in the fact that the intense culture required by the sugar beet not only brings up the condition of the land, thus improving it in both quality and fertility, but the farmer has

almost unconsciously learned the great lesson that the soil yields most richly to him who tills it with the greatest care and wisdom ; that nature gives up her choicest gifts only to him who woos her aright.

But it is not only to things agricultural that an impetus is given by such a factory. To supply its daily wants, while running, four cars of coal and two of limestone must be mined, to say nothing of coke and other supplies, such as sugar-bags, or barrels, filter cloths, knives and rubber goods, which alone run up into thousands of dollars each year. Should the number of factories be only trebled, it can readily be seen that several branches of trade would be largely benefited by even the minor articles of consumption. Then there is the building of the factory itself, which means an outlay of nearly half a million dollars. Up to the present time, most of the machinery has been purchased in other countries, with the notable exception of the factory at Lehi, Utah, which is entirely of American manufacture, and has proved beyond question that the ocean need not be crossed for the mechanical part of such plants. It has been claimed that American skill and ingenuity will take hold of anything that Europe can offer and improve upon it, and this fact is in evidence in the construction of the Utah factory, which, admirable as it is in execution, is



ANOTHER VIEW OF THE MAIN FACTORY ROOM.

but the beginning of better things. If we put the cost of such machinery at $250,000, and multiply it by 600, which represents the number of factories of 30 tons capacity required to supply the United States with the sugar that it consumes now, it can easily be seen that that trade alone would have an increase of business to the extent of $150,000,000 —a not inconsiderable amount, which only further emphasizes the fact that the benefits of a beet-sugar plant are immeasurable.

As has been already stated, the culture of the sugar beet is intensive and requires more than ordinary care, unless we measure labor by the results, which should be the standard. The seed, which must be of a quality showing a good pedigree—it being grown, or, rather, bred, to produce the greatest amount of sugar per acre possible—is sown in Northern climates from the middle of April to the middle of May, in soil plowed deeply, and preferably of a rich sandy loam in character, in drills about eighteen inches apart. To insure a good stand, the seed is dropped continuously and quite thickly, and after the first four true leaves have made their appearance, the plants are thinned out, one being left about every six or eight inches.

This part of the work is somewhat laborious, but absolutely necessary, and must not only be done carefully, but at the proper time, for which reason it is usual to make two or three plantings, a week or so apart, in order that this work may not all come at once. The great point in this isolation of the plants is to allow the formation of perfect roots, for if the tap-root does not penetrate straight into the ground, it will be bent, or else forced above ground; and if two plants are left in one place the roots become entwined, in each case injuring seriously the beet as a sugar producer. The ideal shape is long, straight and tapering, with a certain twist to the root that has given to the type the name of "cork-screw." This much being accomplished, the beets must be hoed and cultivated at frequent intervals to clear the ground of weeds and keep the soil loose, until the leaves have grown so large that they shade the ground. They are then "laid by," and are quite able to take care of themselves until harvest time. By this point of "laying by," say the middle of July, the roots have begun to develop considerably, and sugar is, thenceforth, taken on rapidly, being drawn in through the leaves by the action of the sun's rays.

The juice is stored up in minute cells in the root, and one would think that, once imprisoned, the saccharine matter was a certainty; but, fickle almost as the weather itself, it may rise and fall. Consequently, it is important that the harvesting be done just at the proper time, and, to determine this period, samples are taken from the fields from time to time and analyzed. This percentage of sugar should be at least twelve, with a purity co-efficient of eighty, to be marketable for manufacturing purposes, but for profitable working up ought to contain fourteen per cent. of sugar, for, naturally, there are losses in the course of manufacture. Eight per cent. would be a fair extraction for beets with such an average. Unless heavy rains set in and start a second growth after the beets have matured, thus causing a considerable falling off in sugar content, the harvest may begin toward the end of September and continue until the heavy frosts come, and there is danger of the beets being frozen in the ground, say November 15. These dates apply more particularly to Nebraska. In Northern California the period is longer, owing to milder climate, and in Southern California harvesting may begin in July, as it is practicable to commence planting there in February.

The beets are removed from the ground in various ways, but always by some manner of plowing, and then topped by hand just below the crown, the leaves being left on the field, these tops being equally valuable as a fertilizer or as fodder. The roots are then delivered at the factory by wagons or cars, according to the distance necessary to be covered, or, if not wanted at

once, may be stored in silos until required for use. On arrival at the factory, the beets are unloaded in sheds of special construction, where, with good care, they may be safely stored for over a month. They must be kept fairly dry, but may freeze if not allowed to thaw again, in which case they would be worthless. These storage sheds are V-shaped, the bottom terminating in a channel, which is covered over when not in use. As fast as the beets in a certain shed are required, water is conducted into the channel, and by removing the covers one at a time, the roots are fed gradually and floated by the current into the factory.

Once within the walls the revolving arms of the great wash-house shaft carry them slowly through a trough of water, rinsing them thoroughly and turning them over to a scroll which conveys them, now free from water, to a bucket elevator which, in turn, takes them to the top of the house where, after being weighed automatically, and each weighing registered, they fall, half a ton at a time, into a hopper in the bottom of which is a set of rapidly revolving knives. These knives are serrated and cut the beets into little strips, called cossettes, which fall, the moment they are sliced, down a chute into the open mouth of one of the cells of the diffusion battery.

This portion of the machinery is an arrangement of upright vats, varying in number and sometimes arranged in a circle and sometimes in straight rows. Within the cells the extraction of the juice takes place by a sort of steeping process. One is always being filled, one stands ready to fill, and the balance are arranged to form a continuous circuit. For instance, No. 1 having been filled with cossettes, the top is screwed on ; a current of hot water is then forced downward through an opening in the side, which, gathering juice as it goes along, passes out through a false bottom and, by pressure, is forced upward on the outside through a pipe, is reheated and enters the second cell at the top and so on. If there are twelve cells in the circuit, by the time that No. 1 has received twelve saturations it is disconnected, the juice is drawn off and the pulp is emptied out at the bottom. No. 2 then becomes first in a new circuit, and No. 1 is ready to be filled. The pulp, thus released, falls in a wet mass and must be run through a press to relieve it of the excessive moisture. The pulp that is squeezed out goes into the sewer, and is thence conveyed out of doors for use as fodder for stock.

Meanwhile the juice that is drawn off from the diffusion is carried to a measuring tank, the quantity is recorded, and is conducted into the first carbonation tanks—huge upright receptacles of square or cylindrical shape, where a considerable quantity of milk of lime is added to it. The lime and juice are then treated with an injection of carbonic acid gas, which causes precipitation of the lime as soon as it is pumped to the filter presses, which is done directly afterward, the lime taking with it the impurities contained in the beet juice.

In the Norfolk and Chino plants, where the Steffens process has been installed, a change is necessitated and the use of milk of lime is done away with, the saccharate of lime being employed in its place. This process is a patent method for the extraction of sugar from molasses by the use of lime which is ground and bolted, like flour, and is then mixed at a low temperature with the molasses, the resultant substance being afterwards reduced somewhat in consistency by the addition of water and sent to a set of filter presses, the latter differing distinctly from those in the main house in the point that here the fluid is rejected and the solid matter saved. The latter is the saccharate and, as has just been noted, is conveyed to the carbonation to be mixed with the fresh beet juice, or before or after the run of beets, with melted yellows.

From the first carbonation the carbonated juice is carried to the filter presses, a somewhat elaborate and most interesting bit of machinery, where, by means of heavy cloths, hung over perforated frames, the fluid, passing through under heavy pressure, is filtered and

A FILTER PRESS ROOM.

comes out perfectly transparent, a pale yellow in color. The residue, or lime-cake, as it is called, is left in the alternate frames, which are made hollow, in a solid mass of about the consistency of putty. This is conveyed out of the factory as fast as the frames are emptied and is employed as a fertilizer. Excellent results have followed from its use in Europe, but in the United States the farmers have been rather averse to testing its merits, as they have been, in the West, unaccustomed to fertilizing the soil. The juice then goes to a second series of carbonation tanks and is treated over again in a manner similar to that employed in the first. The filtering process is then repeated and the juice, after passing through the mechanical filters, in which bags are used instead of cloths, is ready for the first stage of reduction to sugar proper—evaporation.

This is usually arranged in quadruple effect. The boiling-down produces a substance known as "thick juice," which, after further thorough filtration and clarification, passes into the vacuum pans for the final process of crystallization. It next appears in the form of *masse cuite*, a mixture of crystallized sugar and molasses, which is dropped into a mixer whence it is drawn off to supply the centrifugal machines directly underneath. The mechanism of these machines is perhaps too familiar to necessitate any explanation, but, in brief, the application of its principles to sugar manufacture is as follows :—A cylinder with perforated sides and a thin brass lining, very finely perforated, revolves rapidly, say, from 900 to 1200 times a minute, within a stationary shell of the same shape. A fair-sized machine is forty inches high and of about the same in diameter. A few inches of *masse cuite* is drawn from the mixer into one of the machines which is immediately set in motion. The centrifugal force drives the substance from the bottom to the sides, and the molasses being forced through the perforations, the crystals remain in a solid cake. If refined sugar is being manufactured, it requires but a few minutes to transform the brown mass into a snowy whiteness. A little washing, and it is ready to be dropped into a conveyer which carries it to the drier, for it is still moist when it leaves the machines.

The molasses, meanwhile, has been collected in a tank from which it is

pumped off for storage, or, if the Steffens process is used, it may be worked over again at once. Some factories have also facilities for the rapid crystallization of the molasses in motion, the idea being to do away with the long storage in tanks, and to accomplish in several days what would otherwise be a matter of months. The sugar from the centrifugals is dried in the granulator—a long iron barrel heated by steam—the product entering one end and working toward the other gradually, falling finally through a screen into a chute which terminates in the open mouth of a sack or barrel, and a few minutes later is whisked away ready for the market. This refers, of course, to standard refined sugar, that being the finished product of four of the American beet sugar factories, as they are so far from any of the large refineries that it is deemed more desirable to manufacture and refine under one roof. In Europe, however, raw sugar is the usual direct product of the factories.

The entire process of conversion of the beets into marketable sugar occupies from eighteen to twenty-four hours. After the working up of the molasses, there is still a residue which may be converted into vinegar or alcohol, if there is a market near enough at hand to make shipment profitable. In Europe there is sometimes a distillery connected with the factory, but, so far, the scheme has not been thought practicable in the United States. Should the beet-sugar industry develop there, however, as it promises, the question of the profitable disposition of the by-products will come immediately to the front. Molasses made from beets, unfortunately, contains certain potash salts which render it unpalatable, so that it cannot be utilized for table purposes.

It being undesirable to store sugar beets longer than a few weeks on account of the consequent falling off in sugar content, the annual season is necessarily short, about one hundred days being the maximum duration of a campaign. In Nebraska and Utah the factories start up usually between the middle of September and the first of October. In a warmer climate operations may begin earlier. The mills run night and day continuously, with a short respite on Sunday for cleaning up, until the last beet is sliced. Then the closing down of one station after another commences, and, if there are no low products to work up, the factory is very shortly laid by for the winter, with only a few hands retained for repairs and other odds and ends of work that are inevitable even when the plant is closed down. The average daily output of refined sugar of a factory consuming 350 tons of beetsper diem is about 50,000 pounds, or two car loads of two hundred and fifty sacks each. Such a factory, to be profitable, should, in a good season,

HARVESTING SUGAR BEETS.

work up about 30,000 tons of beets, and market about 5,000,000 pounds of sugar.

Thus, in rounds numbers, a good-sized plant will turn out annually 3000 tons of sugar, and as the American consumption is in the neighborhood of 2,000,000 tons every twelve months, it can easily be seen that over six hundred factories could be supported, or, in reality, two or three hundred more would be required, for we must take into consideratton small plants, say of 200 ton capacity, as well as large ones ; and with a growing population and increasing consumption per capita not less than 1000 could supply the wants of the United States in 1900.

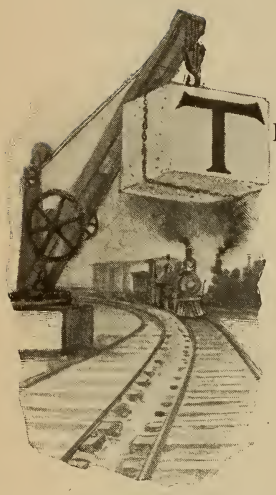
If we deduct from these figures the Louisiana cane crop, which is about 250,000 tons or, better still, the 500,000 tons which it is estimated that the three cane States of Louisiana, Florida and Texas are capable of producing, we still have 1,500,000 tons of sugar that ought to be, and could be, produced in the United States from sugar beets. Just how much of this is being actually produced from that source the following figures for the season of 1893 will show :

| | Pounds. |
|---|---|
| Stanton, Virginia | 36,458 |
| Grand Island, Nebraska | 1,835,900 |
| Lehi, Utah | 3,750,000 |
| Norfolk, Nebraska | 4,107,300 |
| Alvarado, California | 4,486,572 |
| Watsonville, California | 14,500,000 |
| Chino, California | 15,039,867 |
| | 43,756,097 |

The first named factory and the last two did not refine their product ; hence the figures are proportionately larger than they should be to institute proper comparison with the others, but it may be safely said that if they had all turned out standard granulated sugar, the total would not supply the United States with sugar for more than three days. But, small as these figures seem, they are half again as large as those for the year previous, and nearly four times the production of the year 1891, and seventy times as great as the total for 1887. In 1888, 1889 and 1890 the approximate production was four, six and eight million pounds respectively. Nothing could show more conclusively than these figures the rapid development that the industry is capable of during the few years required to put it upon a firm basis and to reduce by experience the cost of production to a point that will permit it to be self-supporting.

# THE INSTALLATION OF EXHIBITS AT THE WORLD'S FAIR OF 1893.

*By William L. Clements.*



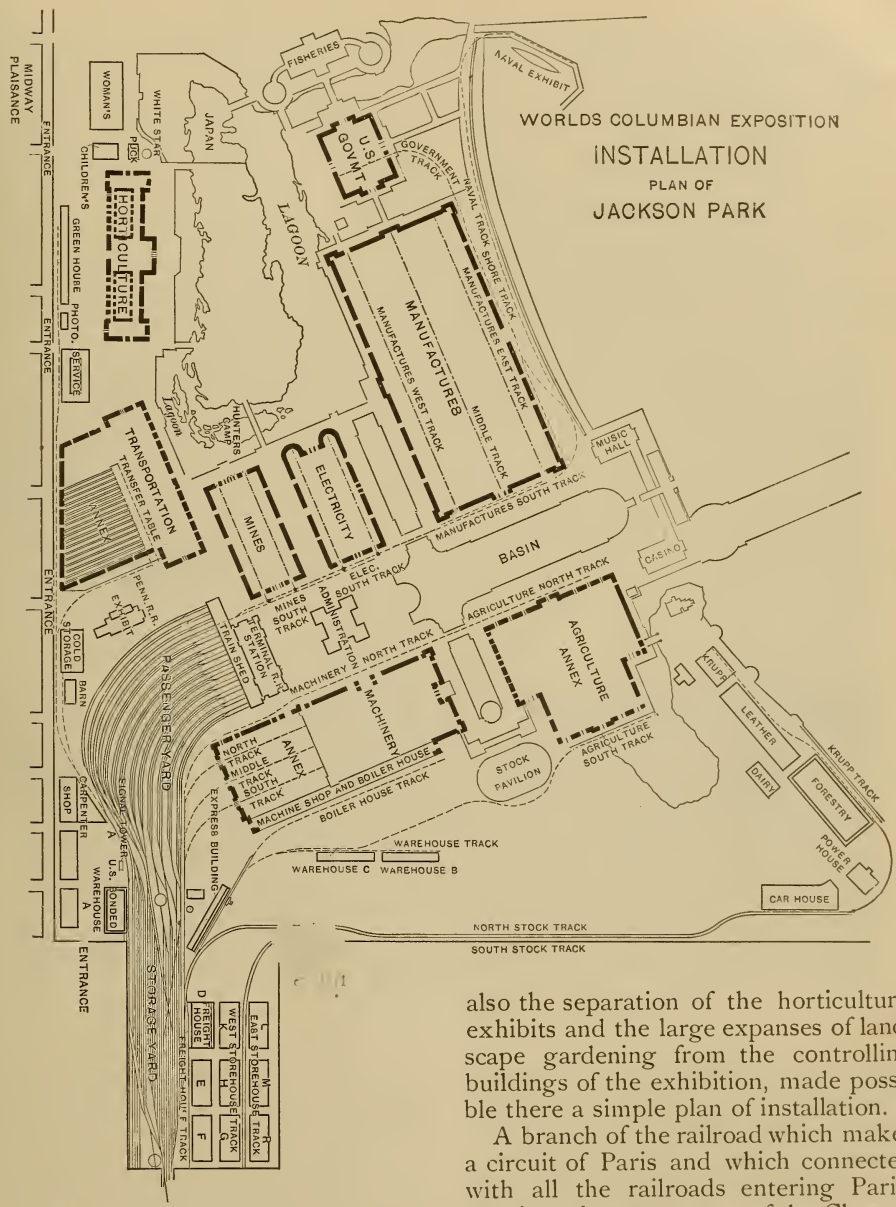
THE transportation department at the World's Columbian Exhibition was given problems for solution which called for great executive and mechanical skill, and which, even at this comparatively late date, may be referred to with interest. In the early sessions of the department and as the magnitude of the undertaking developed, there were presented large results which should be attained for a successful accomplishment of the great project.

Of great importance and underlying much engineering construction was a successful plan for the reception and installation of the immense amount of material and exhibits within the short period allotted for the purpose. The Department of Building Design and Construction presented to the Department of Transportation the artistic buildings and grounds for a satisfactory solution of the problem. As this important work was very satisfactorily performed, it is interesting and instructive to note the methods employed in its accomplishment. That the undertaking is of the past and that similar conditions may never again be presented is probable, but the fact remains that the results there attained were crowning ones in the history of transportation and the means novel in the history of exhibitions.

In the early organization at Chicago there was established by the railroads centering there, a joint agency, through which freight was received and dispatched. The methods of work there used were the same as are ordinarily in service upon American railways. Over this joint agency the Department of Transportation exercised merely supervision, but the duty of delivering and installing was directly in their charge. Arrangement of exhibits and space allotment were under the control of the chief of transportation exhibits, which position Mr. Willard A. Smith ably filled. Other duties, not less important, devolved upon the Transportation Department, including the provision of proper facilities for the transportation of the immense numbers of people who daily visited the grounds. The methods adopted for installation were carefully considered and involved a thorough understanding of appliances available for this service. At no universal exhibition, neither at Paris nor at Vienna, was the magnitude of the exhibits so great, the area of operations so extensive or the period of time for installation so short.

The [illegible]ts covering the investigations a[illegible]udy of the methods of organization and execution at the Paris Exhibition had little information of value applicable to American conditions. Among the laws and regulations of the Paris Exhibition of 1889 it was stated: "As regards handling of articles, all of which is to be at the expense of the exhibitor, the administration will endeavor

WILLIAM L. CLEMENTS has long made a specialty of crane machinery and other special labor-saving appliances, being the chief engineer of one of the largest crane shops in the United States. His close connection with the design and construction of much of the machinery used in putting in the exhibits at the World's Fair lends a special interest to the matter which he presents in this article.

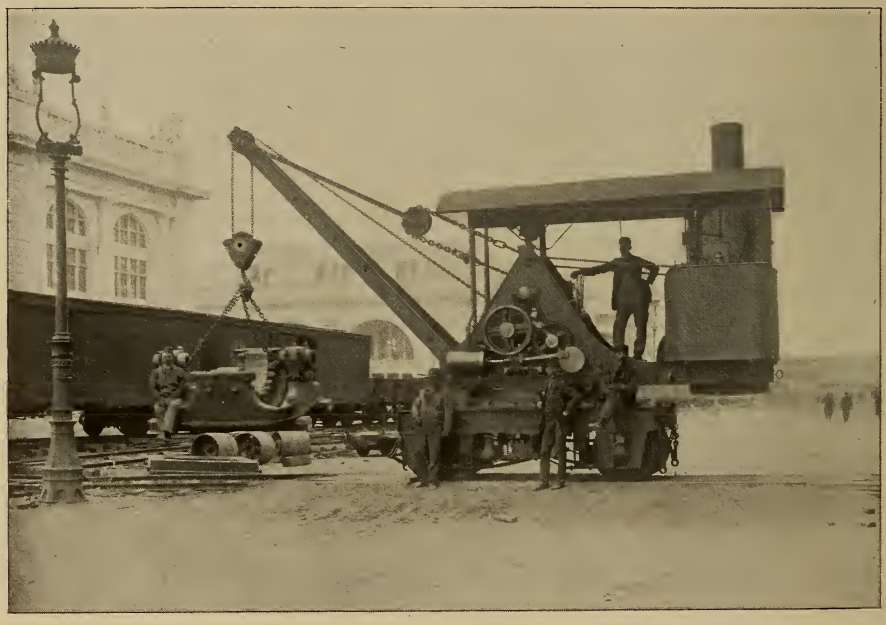



to place at his disposal, in the most practical and economical manner, the tools and workmen necessary to enable him to discharge and unpack the exhibits and repack and forward them." The comparatively small area of about 128 acres, as compared with 800 acres at Chicago, occupied by the Champs de Mars and by buildings with exhibits, also the separation of the horticultural exhibits and the large expanses of landscape gardening from the controlling buildings of the exhibition, made possible there a simple plan of installation.

A branch of the railroad which makes a circuit of Paris and which connected with all the railroads entering Paris, terminated near a corner of the Champs de Mars. From this station, tracks of standard gauge were laid into the grounds and buildings which were used for the delivery of freight before the opening, and for its removal after the close. Auxiliary to this were systems of narrow gauge, portable railways of the Decauville type, which were laid about the grounds and buildings and

were used for moving cases and exhibits from place to place, a specially designed locomotive being employed. Large exhibitors provided their own appliances for handling their exhibits and the English government used two locomotive cranes. Overhead traveling cranes were also provided for use in the machinery exhibit.

The Paris systems were carefully investigated for Chicago and were found poorly adapted to the large areas, the

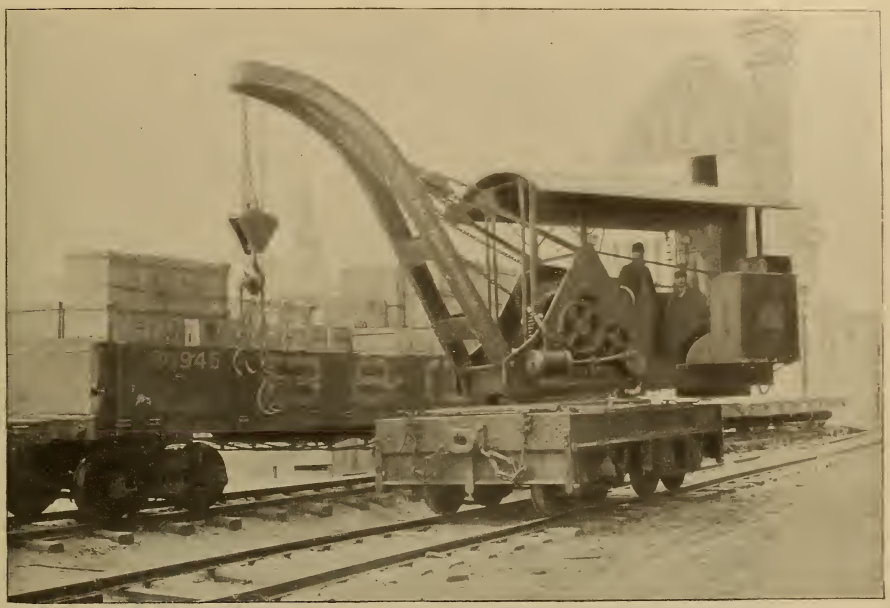


RECEIVING EXHIBITS FOR THE ELECTRICITY BUILDING.

system of gardening and the extraordinary weights necessary to be handled. Without further considering the reasons which led up to the final adoption of the plan as used, the report here given embodies the final conclusions. Through the courtesy of General Manager of Transportation W. H. Holcomb and Assistant E. G. Nourse, the writer is enabled to give this report and also statistics as to the material transported. To Chief of Construction Burnham Mr. Nourse reported in August, 1891, as follows :

"Upon a careful consideration of the matter of installation of exhibits in the various buildings, I beg to submit the following plan, with my reason for recommending same : The system of landscape gardening adopted is such that its perfection will require at least one whole growing season for the propagation of grass, growing plants, etc., thus rendering it impossible to cross such parts with railroad tracks that must remain until the opening of the exhibition. It has been determined that these tracks shall be constructed wholly upon the terraces and upon the lines of the walks, which space can be covered or repaired to the same condition as the balance of the walks in a very short time ; hence, the plan shown upon the drawing herewith submitted. The lines — — — — thereon represent the centre lines of standard railroad tracks connecting with the terminal system. The lines - - - - - - thereon represent the centre lines of tramway and crane tracks.

"For the Transportation Building the railroad track is planned to run up to the transfer table, running parallel



LOADING EXHIBITS FOR SHIPMENT.

with its longest axis, and all installation tracks in the building parallel with its shortest axis. The railroad tracks for the Mines, Electricity, and Manufacturers' buildings are to be laid along the outer edge of the terrace and parallel, having their centres 18 feet from it. A system of crane tracks is planned, upon which locomotive cranes can move from place to place and transfer heavy exhibits from railroad cars to light installation cars and thence to points within the buildings where they can be shifted into place and be unloaded by another locomotive crane. A part of these installation cars shall be designed to carry a maximum load of 30,000 lbs., spread upon 64 square feet of surface.

"The locomotive cranes for service outside of the buildings, and a part of them for service inside the buildings, shall have capacity to carry 30,000 lbs. Such a crane will weigh 64,000 lbs. and is spread upon 128 feet of surface. As the maximum load will be handled only in a few instances, it will be necessary to have only one or two heavy cranes for installation within the buildings. The balance can be of lighter capacity. In order that the cranes may be readily shifted about for their economical use, a turntable is designed to be placed in the outside crane track at each point of intersection with the installation tracks.

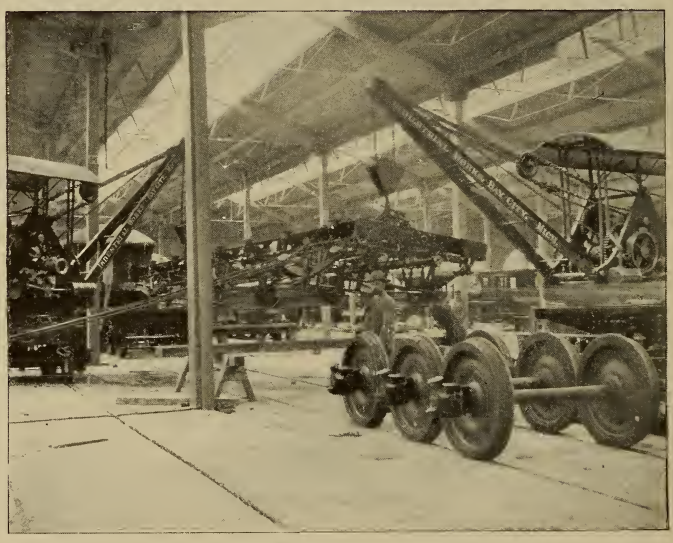
"To carry out the foregoing successfully, three installation tracks shall be laid within the Mines and Mining Building, two tracks in the Electricity Building, and three tracks in the Manufacturers' and Liberal Arts Building as shown. For the Machinery Building three overhead traveling cranes are designed to be constructed and to run along an annex to be built west of the main part of the building. Therefore, it is designed to construct three railroad tracks into the west end of this building, each upon the line of the centre of a traveling crane, and to install heavy pieces directly by means of these cranes from the cars to their final location.

"It is my opinion that, however strongly exhibitors are urged to deliver goods early for installation, much will be delayed to the last few weeks before opening and it is, therefore, desirable that the most complete facilities be provided for the prompt handling of such

heavy pieces as must be handled by machinery."

Plans for the installation of exhibits for the Government, Fisheries and Horticultural buildings were proposed and contemplated simply placing cars within these building and using animal power for these lighter installations.

The report and suggestions of Mr. Nourse having been adopted, the crane builders throughout the United States were requested to submit designs and proposals for furnishing the cranes and



A SCENE IN THE TRANSPORTATION BUILDING.

transfer table. The contracts for the locomotive cranes and transfer table, five seven-ton capacity cranes and two of fifteen tons capacity, were let to the Industrial Works, of Bay City, Mich. One electric traveling crane each was furnished by William Sellers & Co., of Philadelphia, the Morgan Engineering Company, of Alliance, O., and the Yale & Towne Manufacturing Company, of Stamford, Conn.

The work of installation, contrary to official regulations, did not begin until about March 1st, 1893, and from that time proceeded uninterruptedly until after the opening of the exhibition. The formalities with the Customs Department, necessary for foreign exhibitors, required much additional service of the cranes in rehandling packages and in placing machinery. The weight of the material installed expresses but a part of the work performed by the machines.

The following statistics are given by Messrs. Holcomb and Nourse: "In the Transportation Building there were installed 51,275,000 lbs. of exhibits. Part of this came in by team, but all the cars, locomotives and heavy pieces on cars were delivered over the transfer table, and these came in such a way that frequent shifts and changes in location were found to be necessary. Much construction material also was delivered over this table, so that it is safe to estimate that between seventy-five to eighty millions of pounds were handled over the table, and, of course, a like amount went out. The locomotive cranes were used in unloading much of this material

"The weight of other exhibits installed was 145,402,371 lbs. Deducting 19,471,575 lbs. in Machinery Hall, which were installed by the three traveling cranes, we have 125,930,796 lbs.

of exhibits installed in other buildings. Of course, as in the Transportation Building, there was much light material taken to the buildings and unloaded from wagons by hand, but by far the greater portion was handled by the locomotive cranes and much of it, necessarily, several times. Besides, they were used, whenever necessary, to lift heavy loads in any location, and it is safe to say that these cranes loaded the 125,930,796 lbs. mentioned, the same amount, of course, going out. The work of these machines confirms the correctness of this theory of installation."

These remarkable figures express results attained during a period of seven weeks preceding the opening of the exhibition and following its close. Statistics, furnished by the officials of the Paris Exhibition and the civil Government of Paris, are most minute, covering the financial results accruing to each, but are quite silent as to the total tonnage of exhibits handled, and, therefore, accurate comparisons are impossible. It is safe to state, however, that considering the number and nature of the exhibits at Paris and Chicago, there was installed at Chicago nearly double the weight of the Paris exhibits, and the difficulties of such installations were, at the same time, immeasurably greater.

It is interesting to note the features of design of the machines with which these results were accomplished. The illustrations show the general use of the locomotive cranes transferring exhibits to and from the exhibition buildings and placing them upon cars on parallel tracks. Much of the shifting and locomotive work in transferring loaded cars from one part of the grounds and buildings to another were performed by these machines, which were of value for this service also. Lifts of 20 tons and over were often made by two 12-ton capacity cranes, with the weight between the cranes and one-half the weight suspended from each jib. In this position the load might be carried from one place to another. The heavier locomotive cranes, of a weight of approximately 35 tons, were mounted upon eight wheels and were capable of rapid transportation over standard tracks and for service in clearing away track obstructions or wreckage if desired.

The transfer table was operated by an electric motor, had a length of 70 feet and a capacity of 110 tons. The heaviest locomotives, with their tenders, exhibited in the Transportation Building, were pulled upon the table and transported and placed in position by this machine.

The three electric traveling cranes in Machinery Hall handled, approximately, 19,000,000 lbs. of exhibits, or one-ninth of the weight transported by the locomotive cranes and transfer table. Two of the three cranes were of the three-motor type, or a motor for each motion. They were supplied with double trolleys and auxiliary hoisting hooks. The third machine was of the single motor design, with the special features of its designers, William Sellers & Co. These cranes placed such machinery as could not be handled easily otherwise, upon foundations, and were used at times for the transportation of people from end to end of the building.

But a few years ago the accomplishment of these results in this time would have been regarded as impossible. Machinery has shortened the time in producing mechanical results from months into days. Within the memory of a short lifetime the construction and manufacture of nearly every article of demand has been shortened. From an annual capacity in value of less than one-half a million of dollars in 1850, then regarded the apex of manufacturing and executive achievement, there are to-day annual products in value from manufacturing plants exceeding thirty millions of dollars. And whilst it is true that, parallel with this increase in mechanical development, there has been a corresponding increase in animal labor used, it is also quite true that these results are possible from the fact that products are received, manufactured and dispatched with such rapidity, and in this rapidity no factor is of more im-

portance in time-saving than efficient crane machinery.

The use of crane machinery for purposes of installing exhibits is, of course, special, the general use being for service in manufacturing. In such service it has been demonstrated that for miscellaneous service in and about yards and buildings, in the transfer of heavy loads and where tracks are provided for its operation, the locomotive crane is a most efficient and serviceable appliance. The results of operation of the electric transfer table and traveling cranes have shown the reliability and large capacity of these machines and prove conclusively the efficiency of the adaptation of electricity as a motive power.

## Current Topics.

In a paper presented a short time ago before the Institution of Mechanical Engineers of Great Britain, the question of plain throttling *vs.* automatic engines was discussed at some length by an engineer who has been known as a powerful advocate of mere throttle governing. His conclusions were eminently favourable to the economy of the constant-pressure engine rather than to the constant-expansion engine for all powers except small ratios of the normal or most economical work rate, and he advanced an idea which may be productive of practical value, namely, that the best results are to be obtained by varying the expansion of an engine for all loads down to that light load where the economy of constant expansion crosses the economy of constant pressure. At that point he would cease further regulation by varying the expansion and, for any lighter load, govern the engine by the throttle, allowing the expansion to again vary only when the load increased past the critical point at which throttling ceased to be superior to expansion. For engines with loads varying between wide limits it is possible that the combined method of regulation would prove advantageous if it could be worked to practical shape without unnecessary complication of gear and valves.

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Not the least frequent of ocean steamship mishaps, especially during the heavy weather of the winter months, is the disabling of the steering gear. The plan of one vessel utilizing another as a rudder in such a case, followed on at least one occasion that comes to mind just at present, may therefore be

of interest. A towing hawser was, in this instance, taken from the bow of the vessel that was towed, passed to the stern of the towing vessel, and made fast to a point 100 feet or more forward of the stern. At a point near the latter were fitted two purchases, one on the port and the other on the starboard side, for the purpose of deflecting the hawser either to port or starboard, and, by the angle thus made, changing the direction of the pull on the hawser. This, of course, changed the direction of the vessel. In other words, any deflection, either to the right or to the left of the towing line, by means of the purchases, produced the same effect on the towing vessel as putting the helm over to port or starboard.

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TWENTY-NINE miles an hour is the record which the steam launch Hibernia, built last summer by Messrs. Simpson, Strickland & Co., Limited, of Dartmouth, England, has made for herself on several occasions, profiting, it is true, by a favourable current, but going, even against the stream, at the rate of 26½ miles. At these high speeds the bow of the little craft rises clean out of the water and the boat flies along at the top of it, throwing up a double wall of spray in a decidedly suggestive manner. The length of the launch, which belongs to Mr. R. H. Lebat, of Hampton Wick, and which was built from designs by Mr. G. F. De Vignes, is 48 feet 3 inches over all; breadth, 7 feet 3½ inches; draught, 1 foot 4½ inches, and depth of propeller below the water line, 2 feet 5 inches. The boiler is of steel of locomotive pattern, with a barrel $\frac{5}{16}$ of an inch thick, quintuple riveted in the longitudinal seams. The engines are two-cylinder, both high pressure, 7⅛ inches diameter, stroke 6 inches, and make from 750 revolutions per minute up to 1050 revolutions at maximum speed. The propeller has three blades of hammered double shear steel, with carefully prepared surface and knife edge, keyed in a wrought steel boss and is accurately balanced. The engines are of small dimensions, except in the wearing and hard-working parts, and there the dimensions are very large, and at first glance disproportionately strong. Every detail has been most carefully designed, and carried out with equally careful workmanship and finish. The boat was built for Mr. Lebat chiefly for umpire work at regattas and coach-

THE HIBERNIA MAKING TWENTY-NINE MILES AN HOUR.

ing university crews, and from the start has performed admirably under very trying service, having run over more than 3000 miles without repair and little adjustment to the machinery.

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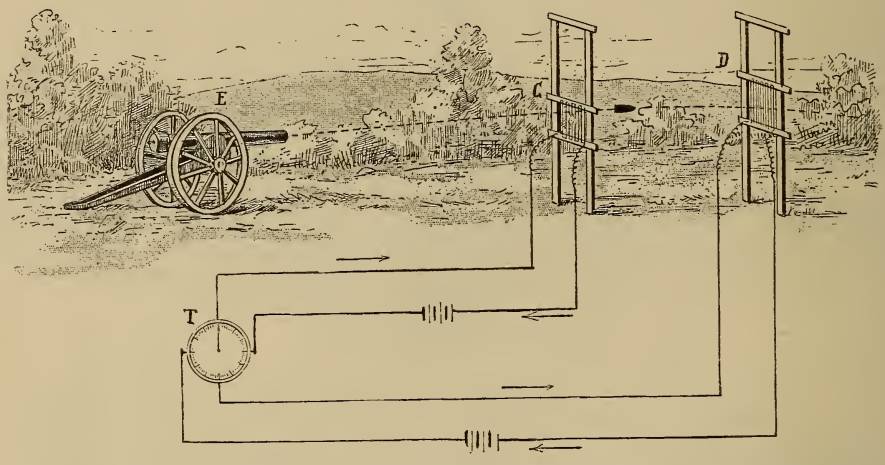
How to measure the velocity of a projectile in its flight from a gun seems to the uninitiated a difficult problem, and yet it amounts to little more than just the division of a certain space passed over by the time which it has taken to do this, both space and time being determined by measurement and




MEASURING THE VELOCITY OF A CANNON BALL.

apparatus of the simplest character. The whole problem, in fact, is explained most graphically by the little diagram on this page. The story which this tells is, briefly, that somewhere in the path of the projectile are placed two wire screens, marked C and D, each formed of a simple frame across which a wire runs back and forth, forming part of an electric battery circuit in which an accurate timepiece, T, is also interposed. As the projectile, on being fired from the gun, passes through the screen C, the circuit of which it is a part is broken and the clockwork is started, the index originally pointing to zero. On passing through the other screen, D, the projectile interrupts the second circuit, with the effect of instantly bringing the clock mechanism to a stop. Knowing, then, the exact distance between the two screens, usually several hundred feet, it follows that by dividing it by the number of seconds or fractions of a second marked on the clock dial, representing the time which has elapsed during the passage of the projectile from screen C to screen D, we obtain the number of feet per second which the projectile was traveling. Nothing much simpler could well be devised, the whole secret of satisfactory measurement lying in the accuracy of the time determination in which even so small a thing as a small fraction of a second becomes a factor of the utmost importance.

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Another example of the growing appreciation of gas engines for all kinds of work comes from France, where a company was formed a short time ago for the purpose of establishing a line of barges to ply on the river Seine between Havre and Paris, the barges to be driven by gas engines and to carry their own supply of gas, compressed into steel tanks. For propelling boats of moderate size, gas engines, working with gasoline vapour, have been pretty well known for a number of years, but their combination aboard ship with gas

reservoirs, as proposed in this new enterprise, and their application to vessels of the comparatively large size of which the French barges are said to be, may be regarded as in the line of a distinct departure into a new field.

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THE gas, according to the available information, is to be produced at a small works located about midway between Paris and Havre, and is to be stored in the gas-holders under a pressure of about 1400 lbs. per square inch. The first barge to be fitted is an iron vessel having a length of 98½ feet, a breadth of 18 feet and drawing 7 feet 4½ inches of water. It is divided into four water-tight compartments, in the forward one of which are located the quarters of the captain and the crew. The cargo will be carried in the two central compartments, while the engine will be placed in the stern. The gross tonnage of the vessel is 300, but the quarters of the crew and the space occupied by the engine are so small that a cargo of 250 tons can be carried. The gas holders are steel tubes having an outside diameter of 9.84 inches, a thickness of 3.1 inches and a length of 16.4 feet. Each tube weighs 715 lbs. and will hold 777 cubic feet of gas at the stated pressure of 1400 lbs. per square inch. There are eighty of these tubes and they are connected to one another by flexible tubes. In order to prevent accidents and economize space, they will be placed on the captain's bridge, so that, should any leakage occur, there can be no danger, as the gas will escape directly into the atmosphere. The gas will be reduced down to the desired pressure for the engine by special apparatus. The engine to be used is of the vertical, two-cylinder type, of about 40 horse-power capacity, with cranks set at right angles, and on one end of the shaft there will be a fly-wheel for starting. A two bladed, reversible propeller will be used. It now remains to be seen what the commercial features of the enterprise will be.

ELECTRIC harness lights for carriage use were probably first employed in connection with one of the carriages of the German Emperor and were designed for the convenience of the coachman in driving along dark thoroughfares. How quickly their advantages were realized is partly shown by the fact that a Berlin firm is now making a specialty of this particular application of electricity, and headlights, disposed somewhat after the manner shown in the annexed little sketch, promise soon to become everyday affairs. The electric wires, which are arranged along the harness, are contained in India rubber tubes which are sewn into the leather, so as to be protected from rain and damage, and the current is supplied from a storage battery of from four to six cells, arranged in a box weighing from about 40 to 55 pounds. The cells are ebonite boxes filled with a gelatinous mass, no acid fluid being used. The battery measures only about 8 by 10 inches and can be easily stowed away under the coachman's seat.

AN ELECTRIC CARRIAGE HEADLIGHT.

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REFERRING once more to the use of water jets as a means of earth excavation, of which mention was made in these pages a short time ago, it may not be uninteresting to recall that early in the sixties Capt. W. H. Stevens, then of the United States Engineer Corps, was engaged in building an iron lighthouse near Galveston, in Texas. The platform carrying the plant for sinking the screw piles intended for the foundation was wrecked by a storm, and the mass of ironwork was soon firmly imbedded in the sand beneath. In the attempt to recover the lost ma-

terial Capt. Stevens donned a diver's suit and went down to study the effect of a jet of water in loosening the buried members of the lighthouse. He soon discovered that he himself was firmly anchored in the quicksand, and, on applying the jet to his feet with the intention of freeing himself, was soon buried to his waist. However, signaling to the men above to hoist, and at the same time stirring up the sand with the jet, he was rescued with little difficulty. The experience was not lost upon him, and shortly afterwards he successfully applied the water jet in sinking piles in sand.

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DURING the great civil war in the United States, Col. S. H. Lockett, at that time chief engineer of the Department of the Gulf, filled the Bay of Mobile with obstructions by following substantially the same principles, sinking trunks of trees, three feet in diameter, and sharpened at both ends, into the sand and firmly anchoring them there by the use of a jet of water from a fire engine on a steamboat. The piles were planted from 12 to 20 feet deep, and settled in the sand at the rate of about a foot a second under a jet from a 1½-inch nozzle on a 3½-inch hose. The nozzle was held by two staples near the point of the pile, and by a rope passed through the staples. Five thousand piles were planted in this manner, furnishing substantial proof of the comparatively early recognition of the value of water jets as excavators.

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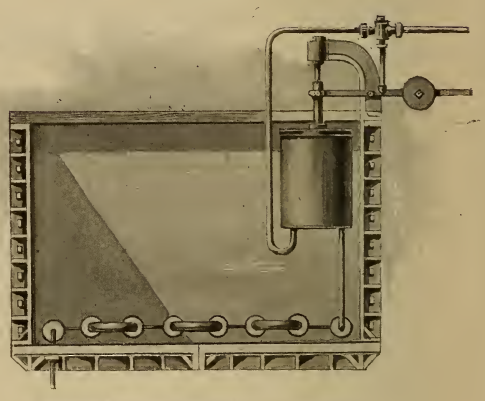
ONE of the several interesting appliances shown at a recent engineering exhibition was a new form of temperature regulator for hot water tanks, designed to maintain, as its name would indicate, a uniform degree of heat in liquids. It was nothing more than a hollow metal cylinder, open at the bottom like a diving bell, but closed at the top, except that the cover was provided with a small tap to allow air to escape. The cylinder was connected with a steam cock by means of a hinged lever so arranged that when the cylinder rose in the tank the steam supply was cut off, while with its fall the steam valve was opened. On passing through the supply valve the steam was first conducted to a small coil inside the regulator, but not in contact with it. The pipe then went to the bottom of the tank, and the steam, having traversed the large coil there, went out by the outlet at the opposite end. A ball cock regulated the admission of fresh



TEMPERATURE REGULATOR FOR HOT WATER TANKS.

water, which was so arranged that the supply pipe delivered it on to the lid of the regulator, which just projected above the surface of the hot water. The steam, on entering the small coil, heated the water enclosed in the regulator; this gave off a certain amount of vapour, though the temperature did not perhaps exceed 100 degrees Fahrenheit. As the water became warmer, the body of vapour increased, lifted the cylinder, and eventually closed the steam valve. Meanwhile the steam, in passing through the large coil, brought the rest of the water in the tank to the same temperature as that which was in the neighbourhood of the small coil underneath the regulator. There was a sliding weight on the prolongation of the lever which connected the regulator with the steam valve, and this partly balanced the weight of the cylinder when water at a comparatively low temperature, say 80 degrees or 90 degrees Fahrenheit, was required in the tank.

To permit of varying temperature, the rod on the top of the regulator was prolonged and weights were placed on it, enabling the temperature of the water in the tank to be raised to any degree below 212 degrees Fahrenheit before the vapour under the lid of the regulator lifted it and so cut off the steam supply. When the tank had been partially emptied, the fresh water which had been turned on by the descending float of the ball-cock fell on the lid of the regulator and condensed the vapour underneath it. The vacuum thus created was, of course, filled by water from the tank, the regulator dropped and opened the steam valve. Thus, when once set to a temperature, the apparatus was automatic, so that not only was waste of steam prevented, but also those using it could be sure that the water was not any warmer than they required it.

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One of the latest innovations in the field of applied electricity and for which, by the way, the engineering profession is indebted to the well known electrical firm of Ganz & Co., of Budapest, is the use of electric power in agricultural pursuits. The experiment, it appears, was made last summer on a large estate in Moravia and involved the operation of an electric central station in connection with a planing mill which was located on the same grounds. The station was equipped with a direct-current generator of 35 ampères capacity, with a voltage of 620, approximating to 30 horse-power, and from it two power circuits, about six miles long, were carried off. One of these supplied current to a grist mill, a farm and a dairy, while the other supplied current to two separate farms. At the grist mill an electric motor was installed simply as an auxiliary to the water power which was ordinarily available. At the dairy there was a 10 horse-power motor operating several pumps and other small apparatus, while each of the farms had a 12 horse-power motor, mounted in a housing on a truck, so that it could be readily taken from one point to another and thus made available for driving threshing machines, irrigating pumps and the like. The power circuits were carried through the fields on pole lines in the conventional way and the electric motors could be connected up at any point where their service was required. The whole installation involved nothing but plain, straight-way engineering and yet it presented in a most striking manner a hitherto not much thought-of possibility of electric power utilization. From an economical point of view the outfit, it has been stated, proved very satisfactory.

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There is at the present time a strong recovery of the interest, felt some years ago, in the production of cheap gas for firing purposes, and which, for some years, has been comparatively little to the front. Some people who tried to fire their boilers with gas very soon gave up the attempt, and the conclusion was arrived at that the steam-producing power of the gas was unequal to that of coal, because of the lack of solid incandescent matter in the flame to produce the powerful heat radiating effects found in a fire of solid fuel. No attempts appear to have been made to introduce incandescent matter in the form of cellular fire-brick to take up the duty of the solid fire. Gas firing was, therefore, pronounced a failure, and gas producers have multiplied slowly and found their field chiefly in producing gas for use in gas engines. Until recently, however, gas engines have been of small power, and the tendency has been to look upon them as substitutes for the steam engine in particular circumstances only. But, as remarked in these pages a month or two ago, the gas engine has latterly reached a stage of development which now warrants its assumption of the title of a large motor. It has been made of several hundred horse-power, and in some instances has displaced the steam engine even for such purposes as driving flour mills and generators in numerous electric lighting stations. It has, in fact, proved

itself sufficiently regular in speed for any purpose. This development of the gas engine has naturally reacted upon gas producers, and these are now made in very different form from the producers of ten years ago. They are neatly designed and cleanly in working, and equally applicable to bituminous and to non-bituminous fuel, and can, therefore, be employed to utilize what has hitherto been considered good-for-nothing rubbish.

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In the most recent producer the duplex system is employed, the producer consisting of a pair of upright, brick-lined cylinders, joined by a horizontal trunk at the upper part, and with air inlets and gas outlets at the base. An intermediate valve controls the inlet of air and emission of gas, so that the two vessels are alternately in receipt of air blast and alternately discharge gas to the holder. The gas produced is eminently fitted for use in gas engines, and it is now beginning to look very probable that in the near future the system of power production hitherto in vogue will be altogether changed. In England, as well as in the United States, the establishment of gas producing plants and gas engines within a short distance of the coal mines themselves has been advocated, the only product sent off the ground to be high-voltage electricity, to be reconverted in the cities to heat or power at will. It has been argued that the expense of this is very largely a question of the conductor, but that this, being of copper and, therefore, always a valuable and permanent asset, can be provided by money secured by debenture bonds bearing a very low rate. Gigantic as such an enterprise may appear, it is but a combination of plant and machinery known, separately, to be a success, and there is, therefore, nothing mechanically impossible about it, while the proved production of power per pound of fuel fed to the gas producer is such as to leave a wide margin for the electrical conversions and reconversions as well as for loss in transmission. In its favor, too, is the abolition of smoke, not merely in the cities, but also at the power stations themselves, for the gas producer makes no smoke. The prospect is an alluring one, and it opens up vast possibilities.

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